CONNECTICUT RIVER BASIN

WESTFIELD RIVER WATERSHED

HYDROLOGIC ANALYSIS FOR FLOOD CONTROL IN WESTFIELD MASSACHUSETTS

A PLANNING AID REPORT

HYDROLOGIC ENGR. SECTION

WATER CONTROL BRANCH

ENGINEERING DIVISION

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HYDROLOGIC ANALYSIS
FOR FLOOD CONTROL IN
WESTFIELD, MASSACHUSETTS

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HYDROLOGIC ANALYSIS FOR FLOOD CONTROL IN WESTFIELD, MASSACHUSETTS

1. INTRODUCTION

A local flood protection project for the city of Westfield, Massachusetts was Federally authorized by the Flood Control Act of 14 July 1960, Public Law 645, 86th Congress, 2nd Session. Subsequently, a Hydrology Design Memorandum was completed in October 1963 and approved by OCE in December 1963. However, before completion of detailed design, the project became inactive, due to withdrawal of local support, and the authorization expired on 22 September 1969. Shortly thereafter, in the Comprehensive Water and Related Land Resources Investigation for the Connecticut River, completed in June 1970, the committee recommended that flood protection for the city be reconsidered and reevaluated. Restudy efforts to date have been mainly those of the Planning Division, which has attempted to involve local officials, group representatives, and the public in the project reformulation process.

This report presents a hydrologic review and analysis of the flood situation at Westfield as it relates to two structural plans of improvement involving dikes and river relocations. The plans are: the originally authorized project (NED Plan), and a modified version of that project, hereafter referred to as the Environmental Quality Plan (EQ Plan). Included are sections on hydrologic description, analysis of floods, standard project flood development, and hydrologic engineering features of the projects as presently conceived. Extensive use was made of the results of earlier hydrologic studies which were considered adequate for comparative costing and project planning studies, involving broad social, environmental, and economic decision-making processes. Pending a decision to proceed on either the NED, EQ, or any other structural flood control plan, more extensive hydrologic engineering studies would be required during any detailed design stage. Also, flood plain zoning assurances would have to be made a part of any further flood control work to prevent the continued relentless development of the Westfield flood plains.

2. WATERSHED DESCRIPTION

The Westfield River, located in western Massachusetts, drains from the eastern slopes of the Berkshire Mountains in a southeasterly direction to its outlet to the Connecticut River in West Springfield, Massachusetts. The total area of the river basin is 517 square miles and the area at Westfield, which is located approximately 8 miles upstream from the mouth of the river, is 497 square miles. Elevations in the watershed vary from a high of 2,505 feet msl in the headwaters in Savoy to about 40 feet msl at the confluence with the Connecticut River. The basin is approximately 50 miles in length and 20 miles wide. The topography of the upper portion of the Westfield River basin, above the city of Westfield, is steep and rocky and drained by many small streams which produce rapid storm runoff. The slopes of the river and its tributaries in the upper mountainous regions are in the 50 feet per mile range, whereas, the slope of the river downstream of Westfield is considerably flatter, averaging about 8 feet per mile. Principle tributaries to the Westfeild River are the Middle and West Branches in the upper watershed, and the Little River which enters the Westfield River at Westfield. The location of these and other tributaries, plus respective drainage areas are shown on plate 1.

3. "NED" AND "EQ" PLANS

The city of Westfield is located astraddle the Westfield River at the foot of the Berkshire Mountains where the river transitions to a flatter flow path through the Provin Mountain range to its confluence with the Connecticut River. The city is bisected by the mainstem Westfield River and generally bordered on the south by the Little River tributary and on the north by the smaller tributary, Powdermill Brook. The "NED" flood control plan was designed to provide flood protection to the main commercial and residential portion of Westfield, lying generally west of East Main Street bridge between the Westfield and Little Rivers. The "NED Plan" consisted of a dike along the left bank of the Little River from Stevens Paper Company dam, just upstream of Southwick Road bridge (Route 202), downstream to near East Main Street bridge (Route 20) and then continuing up the right bank of the Westfield River, tieing into high ground approximately 7,000 feet upstream of Elm Street bridge. This project would have included relocation of a reach of both the Westfield and Little Rivers, and had two street gate openings plus one 176 cfs pumping station for interior drainage.

The "EQ Plan" is a modified version of the "NED Plan" expanded to include protection for that developed northern portion of Westfield lying between the Westfield River and Powdermill Brook. This added protection consists of a dike extending from high ground down along the left bank of the Westfield River and then up the right bank of Powdermill Brook to high ground. Included in this line of protection would be four additional street gates, a railroad gate and a pumping station for interior drainage. With the "EQ Plan", a reach of the dike on the right bank of the Westfield River above Main Street bridge was moved inland to reduce the loss of flood plain storage and offset the loss of storage due to the added flood protection on the north side of the river. General plans of the "NED" and "EQ" Plans are shown on plates 2 and 3. An aerial photograph of Westfield with indicated limits of flooding and lines of protection is shown on plate 5.

Two further considerations in the "EQ Plan" were: (a) The placement of approximately 1,200 feet of the relocated Little River channel in a pressure conduit in order to reduce the impact on real estate takings and relocations, and (b) the installation of gated sluiceways to allow normal summertime river flow to pass through the Westfield and Little River dikes in an effort to maintain the esthetic values of the existing river channels within the protected area. Each of the later two modifications are being incrementally analyzed as environmental add-ons.

4. EXISTING FLOOD CONTROL PROJECTS

a. Corps of Engineers. The Corps of Engineers has two flood control reservoirs in the Westfield basin, namely, Knightville and Littleville. Knightville is located on the Westfield River at Huntington, Massachusetts and controls the runoff from the upper 162 square miles of the watershed. Littleville is a multipurpose water supply and flood control project, located on the Middle Branch in Huntington and Chester, with a drainage area of 52.3 square miles. Pertinent data on these two projects is listed in Table 1.

A third Corps of Engineers project is the West Springfield Local Protection Project. This project is located at the confluence of the Connecticut and Westfield Rivers and provides protection to the city of West Springfield against flooding from both rivers. However, this project is located downstream of the city of Westfield and has no effect on flooding at Westfield.

TABLE 1

KNIGHTVILLE AND LITTLEVILLE RESERVOIRS
PERTINENT DATA

	Knightville	Littleville
Location	Westfield River Huntington, Mass.	Middle Branch Huntington & Chester, Mass.
Purpose	Single purpose - flood control	Multipurpose - water supply & flood control
Drainage Area (sq. mi.)	162	52.3
Flood Control Storage Capacity		
Acre-Feet	49,000	23,000
Inches Runoff	5.6	8.2
Full Pool Area (acres)	960	510
Spillway		
Type	Ogee overflow	Ogee overflow
Length (ft)	400	400
Design Surcharge (ft)	15	15
Design Discharge (cfs)	85,000	92,000

b. Soil Conservation Service. Following the 1955 floods the Soil Conservation Service of the U.S. Department of Agriculture constructed two small flood retention reservoirs in the tributary Powdermill Brook watershed. The SCS also has a system of retention reservoirs proposed for the West Branch watershed, however, the future of this plan is somewhat indefinite at this time. Pertinent data on the existing Powdermill Brook projects and those proposed for the West Branch as well as the Bradley Brook tributary watershed are listed in Tables 2 and 3. The locations of the projects are shown on plate 1.

TABLE 2

POWDERMILL BROOK SCS RESERVOIRS
HAMPDEN AND HAMPSHIRE COUNTIES, MASSACHUSETTS
PERTINENT DATA

Reservoirs	Arm Brook	Powdermill Brook
Purpose*	S,F,R	S,F
Drainage Area (sq. mi.)	3.4	4.6
Net Flood Control Storage		
Acre-feet	581	966
Inches Runoff	3.3	4.0
Full Pool Area (acres)	56	56
Spillway		
Type	Earth	Earth
Length (ft)	184	260

BRADLEY BROOK SCS RESERVOIRS
HAMPDEN COUNTY, MASSACHUSETTS
PERTINENT DATA

Reservoirs	Black Brook	Freeland Brook
Purpose*	S,F,W	S,F,R
Drainage Area (sq. mi.)	2.8	3.0
Net Flood Control Storage		
Acre-feet	864	889
Inches Runoff	5.8	5.6
Full Pool Area (acres)	47	44
Spillway		
Type	Veg.	Veg.
Length (ft)	300	150

* S - Sediment; F - Flood; W - Water Supply; R - Recreation

TABLE 3

SCS PROPOSED RESERVOIRS FOR WEST BRANCH, WESTFIELD RIVER
BERKSHIRE, HAMPDEN AND HAMPSHIRE COUNTIES, MASSACHUSETTS
PERTINENT DATA

Reservoirs	Blandford	Brooker	Cherry	Coles	Cushman	Factory	Rudd	Shaker	Upper Coles	Upper Factory	Walker
Purpose*	S,F	S,F	S,F,R	S,F,R	S,F,R	S,F,R	S,F,R	S,F,R	S,F,R	S,F,R	S,F,R
Net Drainage Area (sq. mi.)	0.8	2.4	2.4	1.4	1.0	4.0	2.3	3.6	2.9	3.9	8.7
Net Flood Control Storage											
Acre-Feet	246	643	631	417	315	1257	579	1139	1187	1107	2110
Inches Runoff	5.8	5.0	4.9	5.6	7.1	5.9	4.7	5.9	7.7	5.3	4.6
Full Pool Area (acres)	72	42	56	26	59	176	84	102	154	101	105
Spillway											
Type	veg.	veg.	veg.	veg.	rock	rock	veg.	veg.	rock	veg.	veg.
Length (ft)	175	100	100	100	30	50	175	400	30	300	400

*S-Sediment, F-Flood, R-Recreation.

c. Other Projects

(1) Cobble Mountain Reservoir. This project is a single purpose water supply reservoir for the city of Springfield, Massachusetts and is located on the Little River, a tributary of the Westfield River at Westfield. The reservoir has a storage capacity of 67,500 acre-feet, equivalent to 27.6 inches of runoff from its contributing watershed of 45.8 square miles. If this project is less than full, at the time of a major storm, it can completely control the flood runoff from its watershed. Even if the project is initially full it produces a desynchronizing effect on flood runoff due to its large amount of surcharge storage. The project has a full pool surface area of 1,120 acres and an overflow spillway length of 135 feet.

(2) Existing Westfield Dike. The history of flooding at Westfield dates back to colonial days and first efforts by local residents to build a dike along the Westfield River occurred prior to 1869. This dike was located on the right bank of the Westfield River upstream of Elm Street bridge. The dike has been overtopped or washed out several times and after the 1938 flood it was rebuilt by the Commonwealth of Massachusetts and extended downstream of Elm Street and tied into high ground a short distance upstream from the mouth of the Little River. This State constructed dike failed in 1955 but has since been repaired and presently provides a degree of protection to a developed section of Westfield. The location of this dike is shown on plate 2.

5. CLIMATOLOGY

a. General. The Westfield River basin has a variable climate typical of New England. The lower part of the basin near the Connecticut River valley has a milder climate than the mountainous upper watershed.

The watershed experiences both continental storms, which move west to east over the area, and coastal storms moving northward up the eastern seaboard, some of tropical origin which may attain hurricane magnitude. Mass curves of rainfall and isohyetal maps for the hurricane associated storms of September 1938 and August 1955 are shown on plate 6.

b. Temperature. The mean annual temperature in the Westfield River basin varies from 44^{o} F in the mountainous regions to about

50° F in the valleys. Temperature extremes have varied from a maximum of 104° F in the lower areas to a minimum of -29° F in the headwaters. Mean, maximum and minimum monthly and annual temperatures at Springfield, Knightville Dam and Stockbridge, Massachusetts are listed in Table 4.

c. Precipitation. The average annual precipitation over the Westfield watershed is approximately 46 inches, quite uniformly distributed throughout the year. Table 5 lists the average monthly precipitation at Peru, Knightville Dam and Westfield, Massachusetts.

d. Snow Cover. The Westfield watershed receives an average of about 70 inches of snowfall per winter. Snow surveys have been taken in the upper part of the basin since 1950. These surveys indicate that the water content of the snow cover normally reaches a maximum about the middle of March. Average, maximum and minimum water contents of the snow cover are listed in Table 6. Flood flows produced by heavy rainfall in conjunction with snowmelt are a threat every year in the basin, however, peak flood flows in the past have been the result of intense rainfall runoff alone.

6. RUNOFF

The U.S. Geological Survey has published streamflow records for various locations in the Westfield River basin dating back to 1905. At the present time that agency maintains four gaging stations in the basin with one located at Westfield. These flow records, particularly those during flood periods, were used extensively in the hydrologic analysis of the watershed.

A summary of discharge records for the four stations is presented in Table 7. The average annual runoff for the period of record for the Westfield River near Westfield, after adjustment for water supply diversion, has varied from 44.1 inches in 1928 to 11.1 inches in 1965. The mean annual runoff for the period has been 25.7 inches (940 cfs) equivalent to approximately 56 percent of average annual precipitation. A summary of the adjusted mean, maximum and minimum monthly and annual runoff at four sites

TABLE 4

MONTHLY TEMPERATURES
(Degrees Fahrenheit)

Month	Springfield, Mass. Elevation - 190 ft, msl (1904 - 1975)			Knightville Dam, Mass. Elevation - 630 ft, msl (1949 - 1976)			Stockbridge, Mass. Elevation - 820 ft, msl (1932 - 1975)		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum
January	26.8	68	-18	21.4	62	-24	22.5	65	-29
February	27.8	74	-18	23.2	64	-25	23.4	63	-28
March	36.7	87	-11	31.7	74	-15	32.3	82	-17
April	48.4	93	10	44.4	92	10	44.1	89	9
May	59.5	97	27	54.8	93	23	55.1	92	24
June	68.4	101	32	64.7	99	32	63.4	92	30
July	73.3	104	30	69.2	99	40	67.8	97	37
August	71.5	102	39	66.8	100	31	65.8	93	32
September	63.7	102	26	58.9	100	24	58.7	91	24
October	53.5	90	20	48.8	88	15	49.0	87	11
November	42.2	83	4	37.9	81	2	38.6	79	-8
December	30.5	66	-16	26.1	65	-19	26.6	63	-21
ANNUAL	50.2	104	-18	45.6	100	-25	45.6	97	-29

TABLE 5

MONTHLY PRECIPITATION
(Depth in Inches)

Month	Westfield, Mass. Elevation 220 feet msl Period of Record - 71 Years (through 1976)		1965	Knightville Dam, Mass. Elevation 630 feet msl Period of Record - 28 Years (through 1976)		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum
January	3.11	7.52	0.77	3.16	6.40	0.75
February	3.32	6.75	1.24	3.18	5.11	1.24
March	3.76	9.71	0.27	3.79	10.18	1.28
April	3.96	8.72	0.75	3.63	5.97	0.82
May	3.78	7.08	0.88	3.58	6.73	0.95
June	3.98	10.09	0.39	3.59	9.12	0.57
July	3.83	10.06	0.32	3.40	7.71	1.12
August	4.08	26.85	0.71	4.02	15.27	1.06
September	4.01	12.41	0.24	3.54	8.06	1.38
October	3.53	12.50	0.05	3.51	16.95	0.42
November	4.07	9.79	0.40	4.25	8.11	0.81
December	3.88	8.90	0.60	4.17	9.38	0.65
ANNUAL	45.31	70.33 1955	29.69	43.82	62.36	32.15

Month	Chester, Mass.* Elevation 600 feet msl Period of Record - 59 Years (through 1976)			Peru, Mass.** Elevation 1860 feet msl Period of Record - 36 Years (Ends 1969)		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum
January	3.50	6.83	0.57	3.73	7.31	1.00
February	3.34	5.77	1.26	3.28	6.58	0.93
March	3.92	10.49	0.21	4.16	10.32	1.25
April	3.85	8.37	0.75	3.76	6.43	0.68
May	4.37	9.92	0.79	4.03	7.77	0.92
June	4.46	14.31	0.23	4.33	10.55	1.53
July	4.22	10.16	1.01	4.60	10.88	1.73
August	4.44	18.44	0.54	3.76	14.07	0.78
September	4.07	12.61	0.40	4.66	12.36	0.68
October	3.75	17.51	0.00	3.65	14.37	0.76
November	4.63	11.01	1.00	4.27	8.35	1.13
December	4.13	11.39	0.76	3.93	10.37	1.14
ANNUAL	48.68	76.15	32.23	48.20	65.42	34.73

*Discontinued in 1957, new station located in vicinity of the original station since 1962.

**Discontinued in 1969.

in the basin are shown in Table 7. It is noted that though precipitation is quite uniform throughout the year, much of the winter precipitation is in the form of snow. As a result approximately one-third of the annual runoff occurs during snowmelt in March and April.

TABLE 6

WATER CONTENT OF SNOW COVER
(in Inches)

Period of Record - 28 Years

	February		March		April	
	1	15	1	15	1	15
Maximum	5.2	7.3	8.0	9.5	9.3	3.6
Minimum	0.3	0.2	0.0	0.0	0.0	0.0
Average	2.9	3.5	4.0	4.0	2.7	0.6

7. FLOOD HISTORY

The history of flooding at Westfield dates back to Colonial days and there are historic accounts of 15 damaging floods during the period 1776 to 1900. However, hydrologic data on these early floods is very meager or nonexistent. Hydrologic records commenced about the beginning of this century and since 1900 there has been six major floods at Westfield.

The November 1927 flood resulted from heavy rains on 2-4 November, falling on ground saturated from excessive rains during the previous month. The flood of March 1936 was caused by four distinct storm centers which passed over the northeastern part of the United States between 9 March and 22 March. The runoff from these rains was augmented by considerable snowmelt. The September 1938 flood resulted from the heavy rainfall accompanying a tropical hurricane that passed over New England on 21 September. The flood on December 1948 resulted from heavy rains falling on frozen ground with some initial augmentation from snowmelt. The flood of August 1955, the maximum flood of record at Westfield was caused by rainfall associated with hurricane Dianne. This flood was exceptionally severe because the storm was centered over the lower

TABLE 7

MONTHLY RUNOFF
WESTFIELD RIVER WATERSHED

Westfield River
at Knightville, Mass.(1)
(D.A. = 162 square miles)
1909 - 1974

Month	Average CFS	Average Inches	Maximum CFS	Maximum Inches	Minimum CFS	Minimum Inches
January	279	2.0	1305	4.8	46	0.3
February	260	1.7	667	4.3	65	0.4
March	614	4.4	2050	14.6	158	1.1
April	923	6.4	1757	12.1	302	2.1
May	433	3.1	910	6.5	166	1.2
June	231	1.6	829	5.7	41	0.3
July	122	0.9	479	3.4	21	0.2
August	98	0.7	745	5.3	16	0.1
September	115	0.8	986	6.8	16	0.1
October	153	1.1	1394	10.8	18	0.1
November	288	2.0	1155	7.1	39	0.3
December	307	2.2	1033	7.4	69	0.5
Water Year	321	26.9	537	45.1	137	11.5

Middle Branch Westfield River
at Goss Heights, Mass.(2)
(D.A. = 52.6 square miles)
1910 - 1974

Month	Average CFS	Average Inches	Maximum CFS	Maximum Inches	Minimum CFS	Minimum Inches
January	95	2.1	213	4.7	15	0.3
February	85	1.7	239	4.7	17	0.4
March	208	4.6	653	14.3	60	1.3
April	290	6.2	594	12.6	85	1.8
May	132	2.9	280	6.1	41	0.9
June	66	1.4	351	7.4	4	0.1
July	32	0.7	150	3.3	5	0.1
August	27	0.6	316	6.9	3	0.1
September	32	0.7	328	7.0	1	0.1
October	51	1.1	507	11.1	4	0.1
November	98	2.1	366	7.8	9	0.2
December	108	2.4	351	7.7	18	0.4
Water Year	103	26.5	182	47.1	43	11.0

West Branch Westfield River
at Huntington, Mass.
(D.A. = 93.7 square miles)
1935 - 1974

Month	Average CFS	Average Inches	Maximum CFS	Maximum Inches	Minimum CFS	Minimum Inches
January	170	2.1	404	5.0	49	0.6
February	169	1.9	371	4.2	44	0.5
March	347	4.3	1089	13.5	121	1.5
April	508	6.1	1067	12.0	158	1.9
May	234	3.0	452	5.6	81	1.0
June	133	1.6	684	8.2	25	0.3
July	65	0.8	307	3.8	8	0.1
August	56	0.7	630	7.8	8	0.1
September	58	0.7	575	6.9	9	0.1
October	97	1.2	1033	12.8	16	0.2
November	167	2.0	542	6.5	25	0.3
December	202	2.5	662	8.2	40	0.5
Water Year	182	27.0	287	41.7	74	10.7

Westfield River(3)
at Westfield, Mass.
(D.A. = 497 square miles)
1914 - 1974

Month	Average CFS	Average Inches	Maximum CFS	Maximum Inches	Minimum CFS	Minimum Inches
January	840	2.0	2211	5.2	196	0.5
February	812	1.8	1761	3.9	234	0.5
March	1700	4.1	5515	12.9	618	1.5
April	2405	5.5	4908	11.1	855	1.9
May	1233	2.9	2465	5.7	458	1.1
June	693	1.6	1926	4.4	181	0.4
July	432	1.0	1690	3.7	114	0.3
August	340	0.8	3393	7.9	83	0.2
September	380	0.9	2941	6.7	89	0.2
October	439	1.1	4879	11.4	103	0.2
November	846	2.0	3384	7.7	202	0.5
December	934	2.2	2174	5.1	220	0.5
Water Year	941	25.7	1590	44.1	368	11.09

(1) Adjusted for change in storage in Knightville Reservoir since 1943
(2) Adjusted for change in storage in Littleville Reservoir since 1965
(3) Adjusted for change in storage in Knightville, and Cobble Mountain Reservoirs, plus diversion for water supply.

basin resulting in maximum runoff from that portion of the watershed uncontrolled by Knightville Reservoir. The flood of October 1955 was caused by a slow moving storm which passed over New England with heavy amounts of precipitation in the Westfield basin. The greatest flows at Westfield since 1955 occurred in June 1972 and December 1973 when moderately intense rainfalls resulted in peak flows of just over 12,000 cfs at Westfield. Had it not been for Knightville and Littleville reservoirs it is estimated that the peak flow at Westfield in December 1973 would have been in the order of 27,800 cfs. A summary of floods at Westfield this century is shown in Table 8. Rainfall maps of the August 1955 and September 1938 storms are shown on plate 6. Profiles for five of the record floods are shown on plate 7.

8. FLOOD FREQUENCIES

Peak discharge frequency analyses consisted of reviewing and updating the 1963 studies, adding the subsequent years of flow data. A statistical analysis was made of flow data at Westfield using the natural flow data, from 1915 to 1941, when Knightville dam was placed in operation, and then extending that natural flow record by correlation with the unregulated West Branch flow record through 1975. Analysis was made using a Log Pearson Type III distribution with an adopted skew of 1.0, based on earlier regional analyses. The resulting natural frequency curve is shown on plate 12. Annual peak flows recorded at Westfield are listed in Table 9.

The modified frequency curve at Westfield, with Knightville and Littleville in operation, was computed as a percentage of the natural frequency curve. The percent reduction was based on the computed effect of the projects on a range of floods. An attempt was also made to statistically compute the modified frequency curve at Westfield by correlating the 13 years of modified data (since completion of Littleville) with the longer term unregulated West Branch record. However, this exercise was generally unsuccessful because not all annual peaks at Westfield are modified by reservoir operation, resulting in a low computed standard deviation which, in turn, results in an exagerated flood reduction by reservoirs in the rarer flood range. This problem was further amplified by the coincidence that there has been no major flood events since 1969 and the greatest drought of record was experienced during the mid 1960's.

TABLE 8

WESTFIELD RIVER FLOODS
WESTFIELD RIVER NEAR WESTFIELD, MASSACHUSETTS
(Drainage Area = 497 Square Miles)

Event	Rainfall (inches)	Observed Discharge (cfs)	Gage Height (ft)
Nov 1927	6	42,500	25.4
Mar 1936	8	48,200	27.2
Sep 1938	10	55,500	29.4
Dec 1948(1)	9	32,200(3)	22.0
Aug 1955(1)	5-19	70,300(4)	34.2
Oct 1955(1)	7-13	31,000(5)	21.8
Dec 1973(2)	3	12,500(6)	13.7

(1) Modified by Knightville
(2) Modified by Knightville and Littleville
(3) Estimated unmodified peak - 48,000 cfs
(4) Estimated unmodified peak - 77,000 cfs
(5) Estimated unmodified peak - 44,000 cfs
(6) Estimated unmodified peak - 27,800 cfs

TABLE 9

ANNUAL PEAK FLOWS
OF WESTFIELD RIVER
AT WESTFIELD GAGE

Water Year	Discharge (cfs)	
1915	22,200	
1916	11,800	
1917	13,000	
1918	7,900	
1919	20,200	
1920	19,200	
1921	16,800	
1922	12,700	
1923	11,100	
1924	32,500	
1925	16,200	
1926	8,880	
1927	9,060	
1928	42,500	Natural
1929	12,600	
1930	7,870	
1931	16,500	
1932	11,900	
1933	34,600	
1934	18,000	
1935	15,800	
1936	48,200	
1937	21,400	
1938	55,500	
1939	12,700	
1940	12,800	
1941	7,730	
1942	12,100	
1943	15,000	
1944	11,700	
1945	12,600	
1946	8,130	
1947	8,030	
1948	11,300	
1949	32,200	
1950	5,960	
1951	18,100	With
1952	14,800	
1953	11,200	Knightville
1954	11,900	
1955	70,300	
1956	31,100	
1957	6,140	
1958	8,740	
1959	8,880	
1960	10,300	
1961	8,080	
1962	8,560	
1963	6,840	
1964	5,820	
1965	4,000	
1966	3,380	
1967	4,910	With
1968	8,110	
1969	11,700	Knightville
1970	8,290	and
1971	6,190	
1972	12,100	Littleville
1973	7,870	
1974	12,500	
1975	11,100	

It should not be inferred that the two reservoirs will reduce all floods an equal percentage. The percent reduction will vary with the orientation of the storm over the basin. The modified curve, shown on plate 12, is considered to represent the average, or typical, reduction for a wide range of storm occurrences.

9. ANALYSIS OF FLOODS

The major floods of record in the Westfield River basin, notably the August 1955 and September 1938 events, were analyzed to determine the hydrologic development of the floods and the contribution of various watershed components to the total at Westfield. The selected watershed components were: the Westfield River at Knightville, the Middle Branch, the West Branch, the local area to Elm Street in Westfield, the Little River and the remaining local area to the Westfield gage. The three upper watershed components were routed to Westfield by "Average Lag" and the total inflow to Westfield was routed through flood plain storage at Westfield using a "modified-Puls" type of reservoir routing. Analysis of the flood plain storage effect at Westfield is discussed in paragraph 12 of this report. Adopted average lag routing coefficients for routing major floods to Westfield, using a 1-hour time interval, were 3-2 for the Middle and West Branches and 4-2.5 for the Westfield River at Knightville.

Runoff hydrographs for the ungaged local areas were patterned after the gaged areas with consideration given to: total storm runoff at Westfield, storm rainfall over the areas, and respective watershed characteristics. The effects of the existing flood control projects were assessed by the removal or addition of their respective component hydrographs routed to Westfield. A hydrograph summary for the September 1938 and August 1955 floods at Westfield are shown on plates 8 and 9. It is noted that the September 1938 event represents a storm more or less centered over the entire watershed, whereas, the August 1955 storm was centered over the lower uncontrolled portion of the watershed.

10. STANDARD PROJECT FLOOD

a. General. The standard project flood for the Westfield River basin was developed from information presented in Engineering Manual 1110-2-1405 and Civil Engineer Bulletin No. 52-8. In all studies to date this flood has been adopted as the design criteria for any Westfield local protection project. The standard project flood is a very intense short duration event resulting in extremely high peak runoff rates from the mountainous Westfield watershed. The flood was developed by applying standard project storm rainfall to selected unit hydrographs.

b. Standard Project Storm. The storm was assumed oriented over the basin and average rainfall amounts were determined for a watershed area of 500 square miles. Infiltration and other losses were assumed a minimum of 0.07 inches per hour. The 24-hour storm volume averaged 8.80 inches and losses totalled 1.40 inches yielding a rainfall excess of 7.40 inches. It is noted that though the total storm excess was only 7.4 inches, a phenominal 5.7 inches occurred in a 3-hour period. Such intensity would produce extremely high runoff rates in the Westfield watershed. Though the August 1955 storm produced large volume rainfall, peak rates of rainfall generally did not exceed 3 inches per 3-hour period. A tabulation of the 3-hour standard project storm rainfall, losses and excess is shown in Table 10.

c. Unit Hydrographs. Unit hydrographs were developed for the component watersheds by analysis of recorded historic floods at the gaging stations on the Middle Branch, West Branch and Westfield River at Knightville. The unit hydrographs having the maximum peak ordinate were generally adopted for the development of the standard project flood. Unit graphs for the ungaged local areas were patterned after those for the gaged areas with adjustment for varying watershed characteristics. Adopted unit hydrographs are shown on plate 10.

d. Flood Development. The standard project flood at Westfield was developed by applying the SPS rainfall to the developed unit hydrographs. Inflow hydrographs were routed through reservoir storage at Knightville, Littleville and Cobble Mountain reservoirs. Outflows were then routed downstream and combined with local contributions at Westfield. The total inflow at Westfield was then routed through flood plain storage at Westfield to determine peak stage and outflow from the Westfield flood plain.

Cobble Mountain reservoir was assumed initially filled to spillway crest and the flood was routed through surcharge storage. Full flood control storage was assumed initially available at Knightville and Littleville. River routings were made using average-lag coefficients developed from analysis of the August 1955 flood. The SPF component hydrographs are illustrated on plate 11.

TABLE 10

STANDARD PROJECT STORM RAINFALL
WESTFIELD RIVER BASIN

Time	Rainfall (inches)	Losses 0.07 Inches per Hour (inches)	Rainfall Excess (inches)	Rainfall Rearranged (inches)
0	0	0	0	0
3	5.92	0.21	5.71	0.05
6	1.48	0.21	1.27	0.11
9	0.47	0.21	0.26	1.27
12	0.32	0.21	0.11	5.71
15	0.26	0.21	0.05	0.26
18	0.18	0.18	0	0
21	0.14	0.14	0	0
24	0.03	0.03	0	0
Total	8.80	1.40	7.40	7.40

11. EFFECT OF RESERVOIRS

a. Knightville and Littleville. Knightville and Littleville flood control reservoirs control the flood runoff from 32 and 10 percent of the watershed at Westfield, respectively. The effectiveness of the reservoirs varies depending on the orientation of the flood producing storm over the watershed. Effectiveness was analyzed by studying major historic floods and the synthetic standard project flood, both with and without the two projects. The projects would reduce a September 1938 type flood, whose storm was centered over the watershed, from a flow of 81,000 cfs at Elm Street in Westfield to about 47,000 cfs. Assuming no Westfield local protection, the projects would reduce the outflow at the Westfield gage from 55,500 cfs to about 36,000 cfs. With an August 1955 flood, whose storm was centered over the lower basin, Knightville reduced the flow at Elm Street from 82,000 to 70,000 cfs and at the gage from 77,000 to 70,300 cfs. The addition of Littleville further reduces the flow to 56,000 cfs at Elm Street and 62,500 cfs at the gage.

With the standard project storm centered over the basin the two reservoirs reduced the resulting flow at Elm Street from 171,000 to 85,500 cfs and at the USGS gage from 136,000 to 89,000 cfs. Littleville has ample storage to control the SPF runoff. Knightville fills and spills but the spillage occurs during flood recession and does not contribute significantly to peak flows at Westfield.

The effects of Knightville and Littleville on the 1938, 1955 and SPF floods are illustrated on plates 8, 9, and 11, and in Tables 11, 12 and 13.

Though the effectiveness of the two projects vary with storm orientation, major flood flows, on the average, are reduced about 52 percent at Elm Street and 42 percent at the Westfield gage by the two projects.

b. Cobble Mountain. Cobble Mountain reservoir has no storage capacity reserved for flood control. However, surcharge storage at the project serves to desynchronize the runoff from its watershed with that from downstream uncontrolled areas. The effect of Cobble Mountain on flood runoff from the Little River for the 1955 and SPF floods is illustrated on plates 9 and 11.

TABLE 11

EFFECT OF FLOOD CONTROL PROJECTS
ON FLOODS IN THE WESTFIELD RIVER

Water Surface Elevations (msl) and Discharge(cfs)
of Westfield River at U.S. Geological Survey
Gaging Station near Westfield, Massachusetts

Frequency (years)	Natural	Modified by Flood Control Projects: Knightville & Littleville Reservoirs Only	Interim Report LPP Plan	Proposed LPP Plan
10	121.1 (34,000)	116.1 (21,000)	116.1 (21,000)	116.1 (21,000)
30(a)	128.2 (55,500)	121.3 (34,800)	121.5 (35,200)	121.7 (35,500)
30(b)	128.2 (55,500)	121.4 (35,000)	121.7 (35,500)	121.9 (36,000)
80(c)	134.0 (77,000)	125.5 (47,000)	126.0 (48,500)	126.5 (50,000)
80(d)	134.0 (77,000)	130.2 (62,500)	131.2 (66,000)	131.5 (67,000)
SPF	149.0 (136,000)	137.5 (89,000)	139.8 (98,000)	140.5 (101,000)

(a) Hypothetical flood similar in magnitude to September 1938 flood but developing uniformly over the entire Westfield River basin.

(b) September 1938 flood as experienced with storm centered over the central portion of the basin.

(c) Hypothetical flood similar in magnitude to August 1955 flood but developing uniformly over the entire Westfield River basin.

(d) August 1955 flood (without Knightville Reservoir) with storm centered in southern part of basin resulting in minimum effectiveness of reservoirs.

TABLE 12

EFFECT OF FLOOD CONTROL PROJECTS
ON FLOODS IN THE WESTFIELD RIVER

Water Surface Elevations (msl) of Westfield
River Upstream of East Main Street Bridge

		Modified by Flood Control Projects		
Frequency (years)	Natural	Knightville & Littleville Reservoirs Only	Interim Report LPP Plan	Proposed LPP Plan
10	124.8	120.2	120.2	120.2
30(a)	131.6	125.2	125.4	125.6
30(b)	131.6	125.4	125.6	125.8
80(c)	136.8	129.2	129.6	130.0
80(d)	136.8	133.6	134.4	134.7
SPF	150.0	140.0	142.0	142.4

(a) Hypothetical flood similar in magnitude to September 1938 flood but developing uniformly over the entire Westfield River basin.

(b) September 1938 flood as experienced with storm centered over the central portion of the basin.

(c) Hypothetical flood similar in magnitude to August 1955 flood but developing uniformly over the entire Westfield River basin.

(d) August 1955 flood (without Knightville Reservoir) with storm centered in southern part of basin resulting in minimum effectiveness of reservoirs.

TABLE 13

EFFECT OF FLOOD CONTROL PROJECTS
ON FLOODS IN THE WESTFIELD RIVER

Water Surface Elevations (msl) and Discharge (cfs)
of Westfield River Upstream of Elm Street Bridge

Frequency (years)	Natural	Modified by Knightville and Littleville Reservoirs and Local Protection Project
10	138.6 (32,000)	132.8 (13,600)
30	144.8 (62,000)	137.8 (28,800)
50(a)	147.6 (81,000)	140.2 (38,600)
50(b)	147.6 (81,000)	142.0 (47,000)
50(c)	147.8 (82,000)	143.8 (56,000)
80	151.2 (104,000)	142.8 (50,500)
SPF	159.0 (171,000)	148.0 (85,500)

(a) Hypothetical flood similar in magnitude to September 1938 and August 1955 floods but developing uniformly over the entire Westfield River basin.

(b) September 1938 flood as experienced with storm centered over the central portion of the basin.

(c) August 1955 flood (without Knightville Reservoir) with storm centered in southern part of basin resulting in minimum effectiveness of reservoirs.

c. SCS Reservoirs. The two existing SCS detention reservoirs in the Powdermill Brook watershed have a total combined watershed of only 8 square miles, or 1.6 percent of the total watershed of the Westfield River at the Westfield gage. Also the combined storage capacity of 1,547 acre-feet is equivalent to 3.7 inches of runoff. Therefore, though the projects reduce peak flows on Powdermill Brook, they have negligible effect on peak flows on the mainstem Westfield River or on the resulting backwater flood levels on Powdermill Brook in Westfield.

In analyzing floods at Westfield the storage capacity of the two SCS projects on Powdermill Brook was combined with the Westfield flood plain storage. This analysis is discussed further in paragraph 12.

The proposed SCS system of 11 retention reservoirs in the West Branch, if completed, would effect the runoff from 33.4 square miles, which is 35 percent of the West Branch watershed and 6.7 percent of the Westfeild River watershed at the Westfield gage. The system would have a total storage capacity of 9,630 acre-feet, equivalent to 5.5 inches of runoff. Based on a very general flood routing analysis this system would reduce the modified standard project flood flow at Elm Street an estimated 15 percent and at the Westfield gage an estimated 9 percent. This would effect a stage reduction of about 2.0 and 2.5 feet at Elm Street and the Westfield gage, respectively.

12. EFFECT OF FLOOD PLAIN STORAGE

A large area in the eastern section of the city of Westfield is a natural flood plain that becomes inundated during flood periods. The flood plain, upstream of the Westfield USGS gage, including backwater areas on Powdermill Brook, Great Brook and the Little River, covers an area of nearly 2,000 acres under flood of record conditions. It is estimated that water temporarily stored on this plain during the August 1955 flood amounted to about 18,000 acre-feet of storage, equivalent to 1.4 inches of runoff from the net watershed of 335 square miles (excluding Knightville watershed). During major short duration floods such flood plain storage can have a significant modifying effect on peak flood outflows. The effect of such storage was studied by routing floods through Westfield using a "modified puls" type reservoir routing. Inflow to Westfield was comprised of the Westfield River inflow (at Elm Street), the Little River, and the remaining localarea. It is estimated that during the

1955 flood of record these three components produced a peak inflow to storage of about 116,000 cfs. The peak outflow was 70,000 cfs. The synthetic standard project flood, modified by Knightville and Littleville, would be reduced from a peak inflow of 144,000 cfs to an outflow of 89,000 cfs.

The local protection projects under study for Westfield would eliminate approximately 1,000 acres of flood plain area, under SPF conditions, thereby reducing the amount of effective flood plain storage. The loss of flood plain storage was considered comparable for either the "NED" or "EQ" Plans. Loss of such storage would tend to increase peak outflows downstream resulting in an increase in stage. The modified peak outflow of a 1955 type flood would be increased from about 62,500 to 67,000 cfs and the SPF would be increased from 89,000 to 101,000 cfs. Summaries of the effects of flood plain storage at Westfield is presented in Tables 11 and 12. The effect of the loss of storage on the downstream flood profile is illustrated on plate 14.

It is noted that though the local protection project would produce some increase in downstream stages during large infrequent floods, the net effect of both the upstream Corps reservoirs and a local protection project is still a substantial reduction for all floods.

13. FLOOD PROFILES

The original project design flood profiles, reported in 1963, were determined by backwater computations using the "step-method" as outlined in EM 1110-2-1409, "Backwater Curves in River Channels". Computed profiles were also compared with observed flood profiles with regard to hydraulic losses.

In current studies, supplemental backwater studies were performed, using the HEC-2 computer program, to determine the effects of changes in the plans of protection. Computations were made with a minimum of surveyed cross sections using a Manning's "n" of 0.035 for channel and 0.050 for overbank areas. Expansion and contraction coefficients were 0.3 and 0.1, respectively. Computations were started at the Westfield USGS gage where starting water surface elevations could be determined from the established stage-discharge rating.

For the "EQ Plan", with protection on both sides of the Westfield River, the design water surface above Elm Street would be raised approximately 3 feet above the original 1963 design level for the "NED Plan". With the Little River pressure conduit, considered in the "EQ Plan", the design water surface at the site of the entrance would be 2.5 feet higher than with the "NED Plan".

The design flood profile on Powdermill Brook for the "EQ Plan" of protection, is governed largely by backwater from the Westfield River except at the upstream end in the vicinity of the proposed Powdermill Brook pressure conduit.

Design profiles were based on design flood flows of 101,000 cfs in the lower Westfield, 28,000 cfs in the Little River, 4,500 cfs on Powdermill Brook and 35,500 cfs on the upper Westfield River. Design profiles are shown on plates 3 and 13. Variations in elevations between the "NED" and "EQ" plans are noted on plate 13.

14. VELOCITIES

Flow velocities in the lower reaches of the Westfield River, Little River, and Powdermill Brook would be affected, under design flood conditions, by backwater from the flat gradient of the river in the downstream flood plain. Therefore, maximum velocities would occur at less than design flow when backwater is minimal. Computations indicated that maximum velocities on the Westfield and Little Rivers generally ranged from 6 to 12 feet per second. These velocities would occur in the river channel and since the toe of the protective dikes would be located on a berm a distance from the channel, the velocity adjacent to the dikes would be considerably less than in the river channel. All relocated river sections and exposed dikes would be riprap protected against erosive velocities.

Velocities on lower Powdermill Brook are low, generally not exceeding 2 to 3 feet per second, due to the relatively flat gradient of about 0.2 percent. Velocities in the upper reach of the Brook generally would not exceed 5 to 10 feet per second.

15. RIPRAP PROTECTION

Tractive forces on streambanks and dikes in the Westfield area are generally low due to the hydraulic character of the flood plain and flat stream gradients. However, because Westfield is an urban area, the riverward side of all dikes and the banks of relocated river sections would be protected with riprap having a design D_{50} minimum of not less than 0.5 foot, thus insuring a stone size and layer thickness adequate to minimize vandalism. Special riprap considerations would be applied to the Little River bypass during any final design due to its relatively steep slope of about 0.6 percent.

16. FREEBOARD

Freeboard is the vertical distance measured from the design water surface to the top of dike or wall. Freeboard is provided to insure that the desired degree of protection will not be reduced by unaccounted factors. Three feet of freeboard was adopted for all earthen dikes under study for Westfield, except along the Westfield River upstream of Elm Street where four feet was adopted. Added freeboard was adopted in this reach because of hydraulic complexities in the area of Elm Street and the increased need for dike safety in upstream areas of a project.

Two feet of freeboard was adopted for concrete walls due to their greater resistance to failure if some overtopping were to occur.

17. LITTLE RIVER CONDUIT

In studies for the "EQ Plan", consideration was given to placing the lower 1,200 feet of the Little River bypass in a pressure conduit, comprised of three 26 feet high by 25 feet wide passageways. The replacement of the open channel with a costly pressure conduit was considered, at the request of planners, to avoid having to relocate new developments in the channel allignment near Little River Road, particularly a new bank building.

The pressure conduit was analyzed for two flow conditions. The first condition was with a peak flow of 28,000 cfs on the Little River with the coincident tailwater of 132.2 feet msl on the Westfield River, and the second was with a peak flow of 20,000 cfs on the Little River with the peak tailwater of the Westfield at 144 feet msl. The latter condition was found most critical for determining maximum hydraulic gradient through the conduit and in the upstream bypass channel. With a flow of 20,000 cfs the velocity in the conduit would be 10 feet per second and the total head loss through the structure would be 3.6 feet, made up of an entrance loss of 0.9 feet, a friction loss of 1.1 feet and an exit loss of 1.6 feet. The location of the conduit is indicated on plates 3 and 4.

18. POWDERMILL BROOK CONDUIT

The "EQ Plan" includes 800 feet of pressure conduit on Powdermill Brook in the vicinity of Highway Route 202, due to insufficient space between buildings for a dike, and to avoid the need for a street gate. The pressure conduit would have two 8 feet high by 19 feet wide passageways, sized to convey the estimated SPF spillage of 4,500 cfs from the upstream SCS reservoirs with a coincident Westfield tailwater of 140 feet msl. The conduit would have a design flow velocity of 15 feet per second and a total head loss of about 10 feet. With the design Westfield tailwater of 146 feet msl the conduit would have a capacity of about 3,000 cfs with the total head loss not exceeding 4 feet. The design tailwater at the outlet of the conduit was considered 146 feet above msl, 2 feet above the design backwater level of the Westfield River at the mouth of the brook.

19. LOW FLOW PASSAGES

At the request of environmental and conservation interests, consideration was given in the "EQ Plan" studies to providing low flow passages through the lines of protection in order to maintain flow in the existing Little and Westfield River sections that would lie within the protected area if the project were built. The inclusion of such flow passages would be a detriment to the flood control integrity of the project, however, the structures were sized for further costing and planning studies. The gates and passageways were sized to pass the estimated average summer flow, which was assumed equal to one-half the all-season average annual flow, with a depth of flow in the river of between 3 and 4 feet. The selected discharges were 50 cfs inflow on the Little River, 250 cfs inflow on the Westfield River and a resulting 300 cfs outflow on the Westfield River. The gates and passageways were sized for a velocity of about 3 feet per second with the adopted discharges, resulting in the following gate sizes:

Little River inflow - two 4 ft x 4 ft gates
Westfield River inflow - three 4 ft high x 8 ft wide gates
Westfield River outflow - four 4 ft high x 8 ft wide gates

20. INTERIOR DRAINAGE

a. General. For a detailed description and analysis of the interior drainage for the "NED Plan" of protection, reference is made to the 1963 Design Memorandum No. 1 for the then authorized Westfield local protection project. The interior drainage area of the "NED Plan" is approximately 2,320 acres. The area was subdivided into five separate subareas with individual storage ponds and gravity outfalls through the dikes. The five ponding areas were namely:

Upper and Lower Riverside Ponding Area
Shepard Street Ponding Area
South Meadow Road Ponding Area
East Main Street Ponding Area

One 176 cfs pumping station was provided at the East Main Street area to facilitate maintaining design ponding levels to about elevation 120 feet msl, but more importantly, the pump was installed to facilitate emptying the large East Main Street storage area within a reasonable period of time following flood events to protect against possible damages from long duration or a sequence of storm events. The 176 cfs capacity was equivalent to a runoff rate of about 0.1 inch per hour from the 1,500 acre subwatershed.

b. Design Criteria. A higher than normal interior drainage design criteria was adopted in 1963 because of the very flashy nature of the Westfield River and the fact that substantial rates of rainfall have occurred concurrently with flood stages in the Westfield and Little Rivers during historic flood events. Because of this characteristic, interior drainage ponding areas were designed for a 20-year frequency rainfall-runoff coincident with flood stages in the rivers. Gravity outfalls were sized to discharge the 100-year frequency storm runoff with normal river stages. For current comparative planning studies, the original 1963 design criteria was retained. If a decision is made to proceed with design of either the "EQ", or "NED", or any other selected plan, then further interior drainage analyses would be required in the preparation of a new feature Design Memorandum.

c. "EQ Plan" Requirements. In the development of the "EQ Plan" of protection the dike along the south side of the Westfield River was moved landward to reduce the amount of encroachment on flood plain storage and offset the loss of flood plain by the addition of the "EQ Plan" of protection on the north side of the Westfield River. This dike realignment resulted in less flood plain encroachment but resulted in about a 60 percent loss in the East Main Street interior ponding area provided in the "NED Plan". In order to maintain comparable design levels of interior ponding and criteria, the East Main Street pumping station was increased to 500 cfs to offset the loss in ponding capacity. A capacity of 500 cfs is equivalent to a runoff rate of 0.3 inch per hour from the 1,500 acre watershed.

The "EQ Plan" of protection for the north side of the Westfield River resulted in the need for a second pumping station. This "north side" protection would have an interior drainage area of about 300 acres. Drainage would be to the east and would be discharged to Powdermill Brook via a pumping station located at the easterly end of the protected area. Using the originally adopted "NED" design criteria, and assuming 3 acres would be preserved at the station for ponding up to 3 feet in depth, a pumping capacity of 160 cfs was selected for costing purposes. This capacity is equivalent to a runoff rate of 0.5 inch per hour from the 300 acres.

Pumping station sites and ponding areas are shown for the "NED" and "EQ" plans on plates 2 and 3. Comparative pumping requirements for the two plans are shown in Table 14.

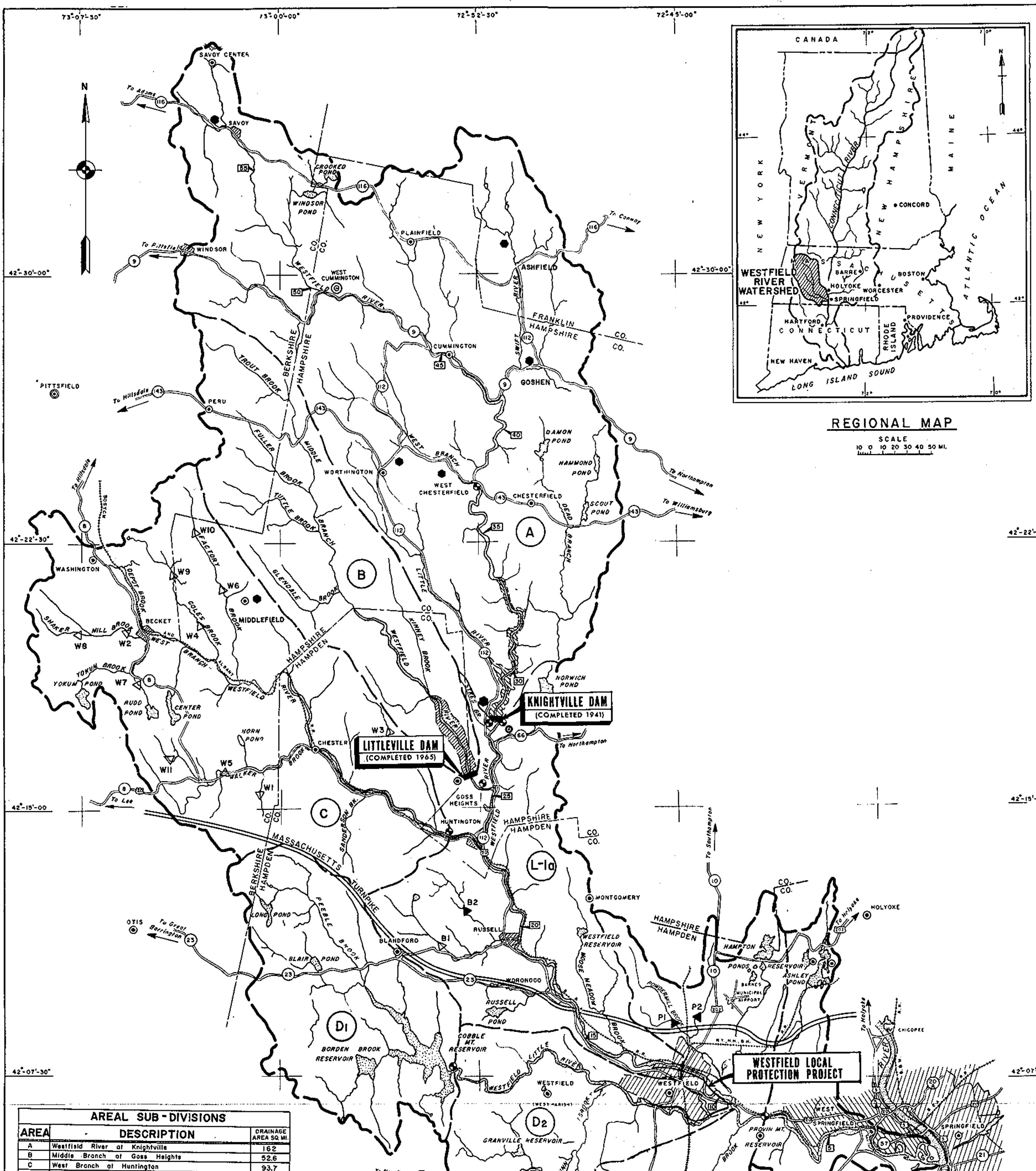
TABLE 14

COMPARATIVE PUMPING REQUIREMENTS

Station	NED Plan	EQ Plan
East Main Street Station	176 cfs	500 cfs
Union Street Station	None	160 cfs

21. OPERATIONAL CONSIDERATIONS

Due to the flashy nature of the Westfield River, flooding can develop within a 2 to 3 hour period after intense rainfall. Therefore, operational requirements should be an important consideration in any flood control plan for Westfield. Operational requirements for the "NED" flood control plan would be less than those for the "EQ Plan". The "NED Plan", with two street gates, four sluice gates and one pumping station, would require an estimated minimum staff of six to eight men to effectively operate during a flood. The "EQ Plan" with as many as seven street gates, seven sluice gates and two pumping stations would require an estimated minimum of at least 16 to 20 men to effectively operate during a flood.



AREA	DESCRIPTION	DRAINAGE AREA SQ. MI.
A	Westfield River at Knightville	162
B	Middle Branch at Goss Heights	52.6
C	West Branch at Huntington	93.7
D_1	Little River at Cobble Mountain Reservoir	45.8
D_2	Little River - Cobble Mountain Reservoir to Mouth	38.2
L-1a	Local Area - Knightville to Elm Street Bridge	57
L-1b	Local Area - Elm Street Bridge to Westfield Gage	47
	Westfield River at Westfield Gage	497
TOTAL WESTFIELD RIVER AT MOUTH		517

LEGEND

- STREAM GAGING STATIONS.
- PRECIPITATION GAGES.
- PRECIPITATION AND TEMPERATURE GAGES
- NED SNOW SURVEY SITE
- SCS EXISTING PROJECTS
- SCS PROPOSED PROJECTS

WATER RESOURCES INVESTIGATION
CONNECTICUT RIVER BASIN

WESTFIELD RIVER BASIN MAP

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE NO. 1

CORPS OF ENGINEERS

U. S. ARMY

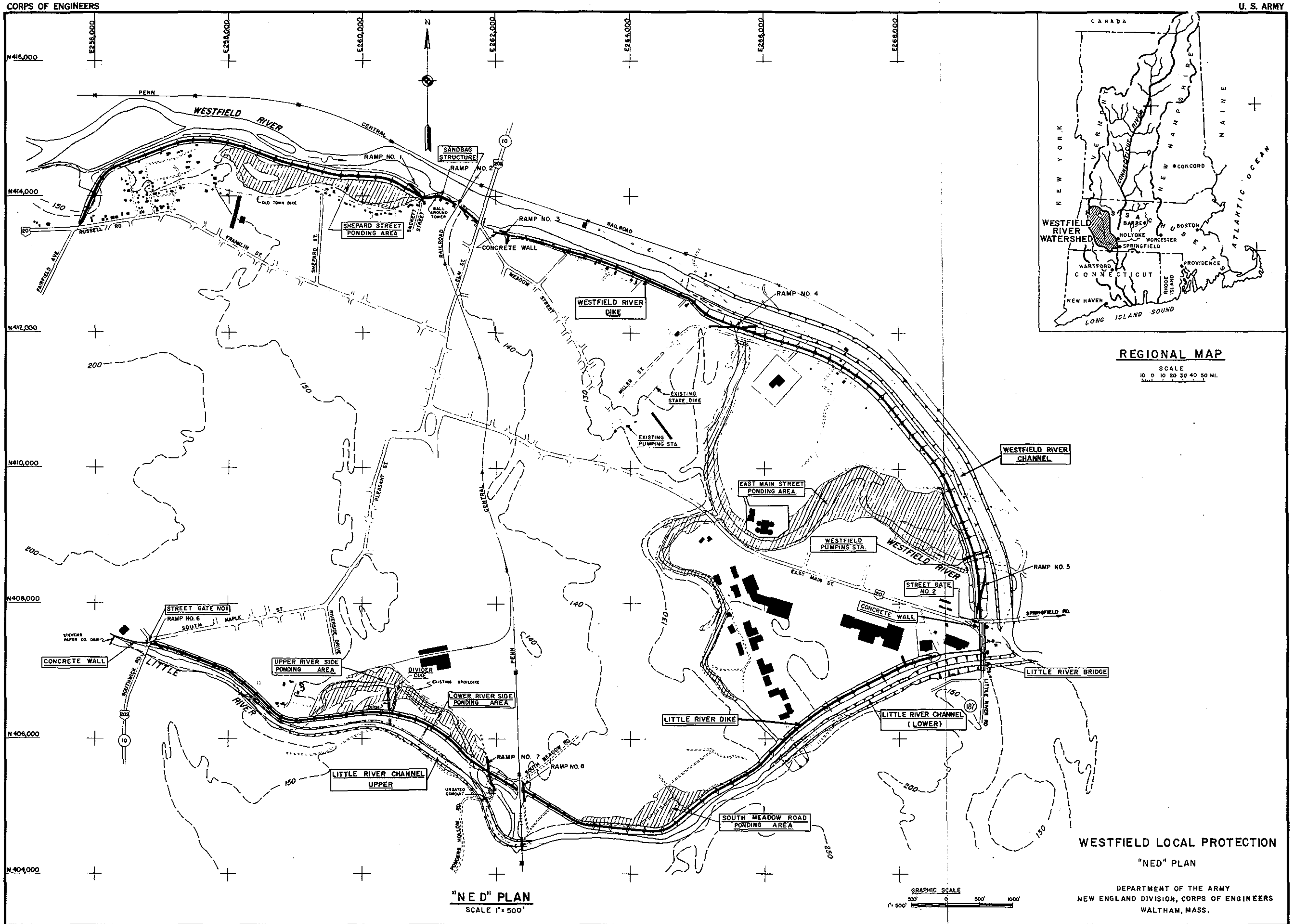
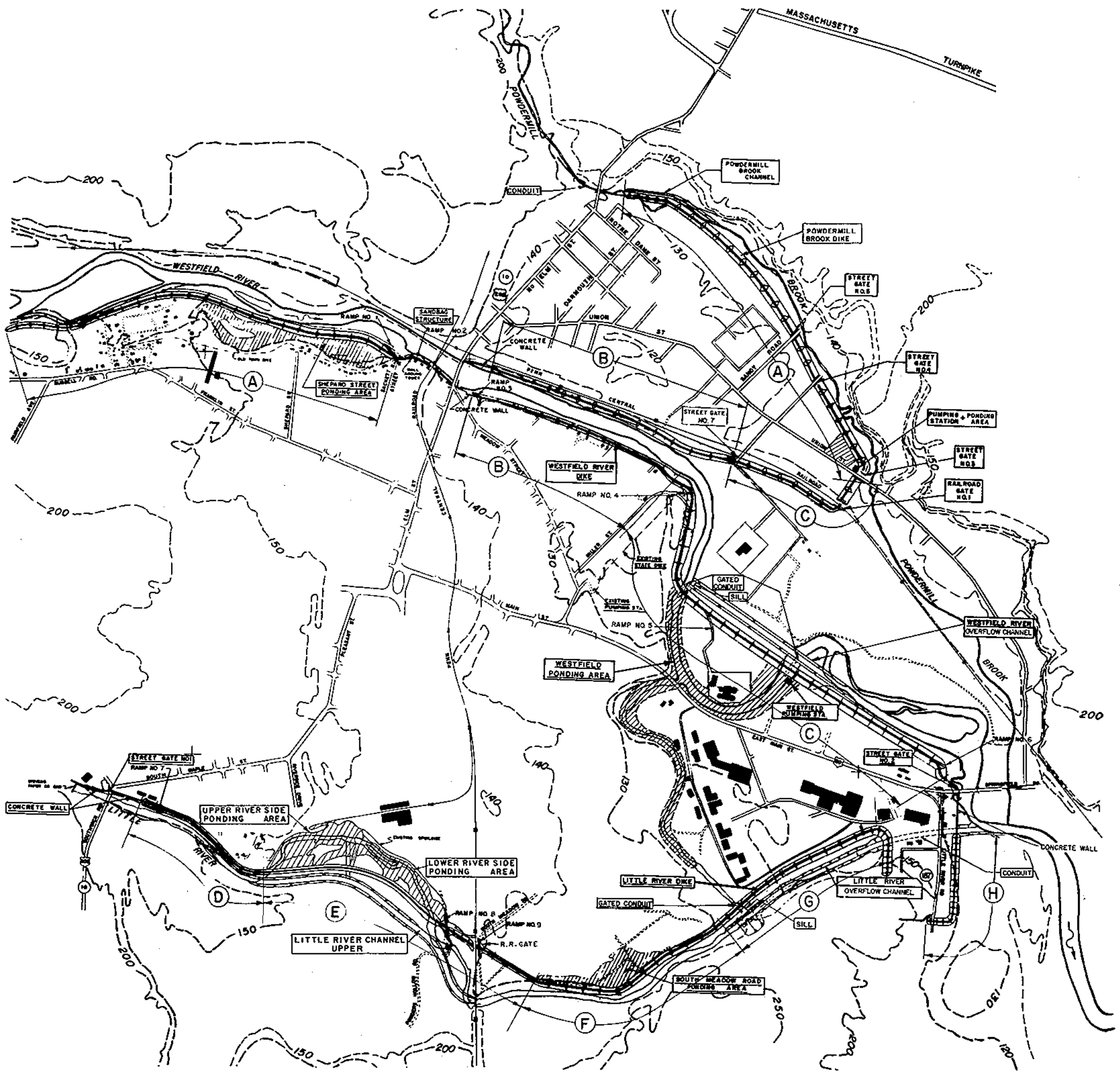
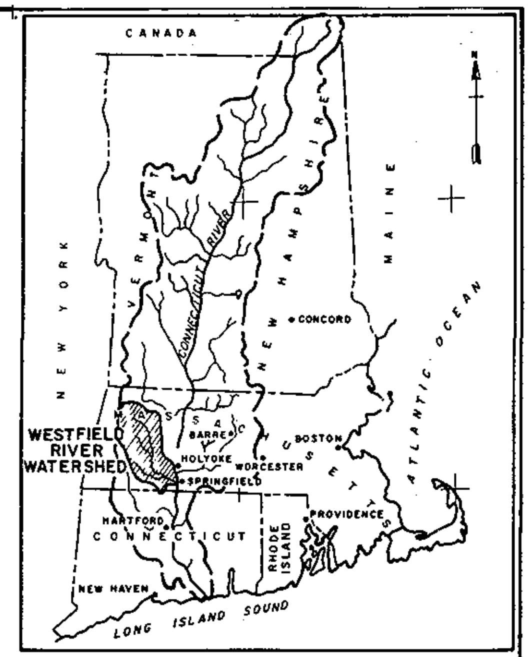


PLATE NO. 2



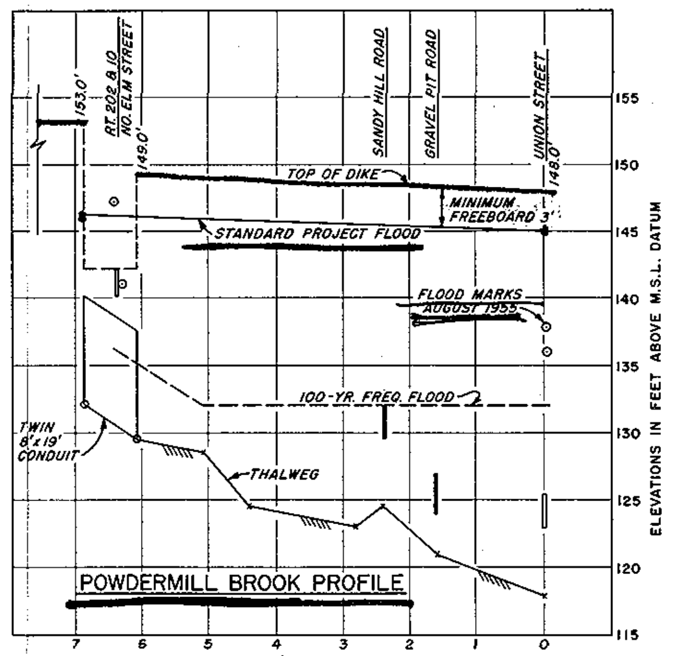
"E Q" PLAN



REGIONAL MAP

SCALE

10 0 10 20 30 40 50 MI.



POWDERMILL BROOK PROFILE

SCALE IN FEET

1000 500 0 1000

WESTFIELD LOCAL PROTECTION

"EQ" PLAN

MAY 1978

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

CORPS OF ENGINEERS U. S. ARMY

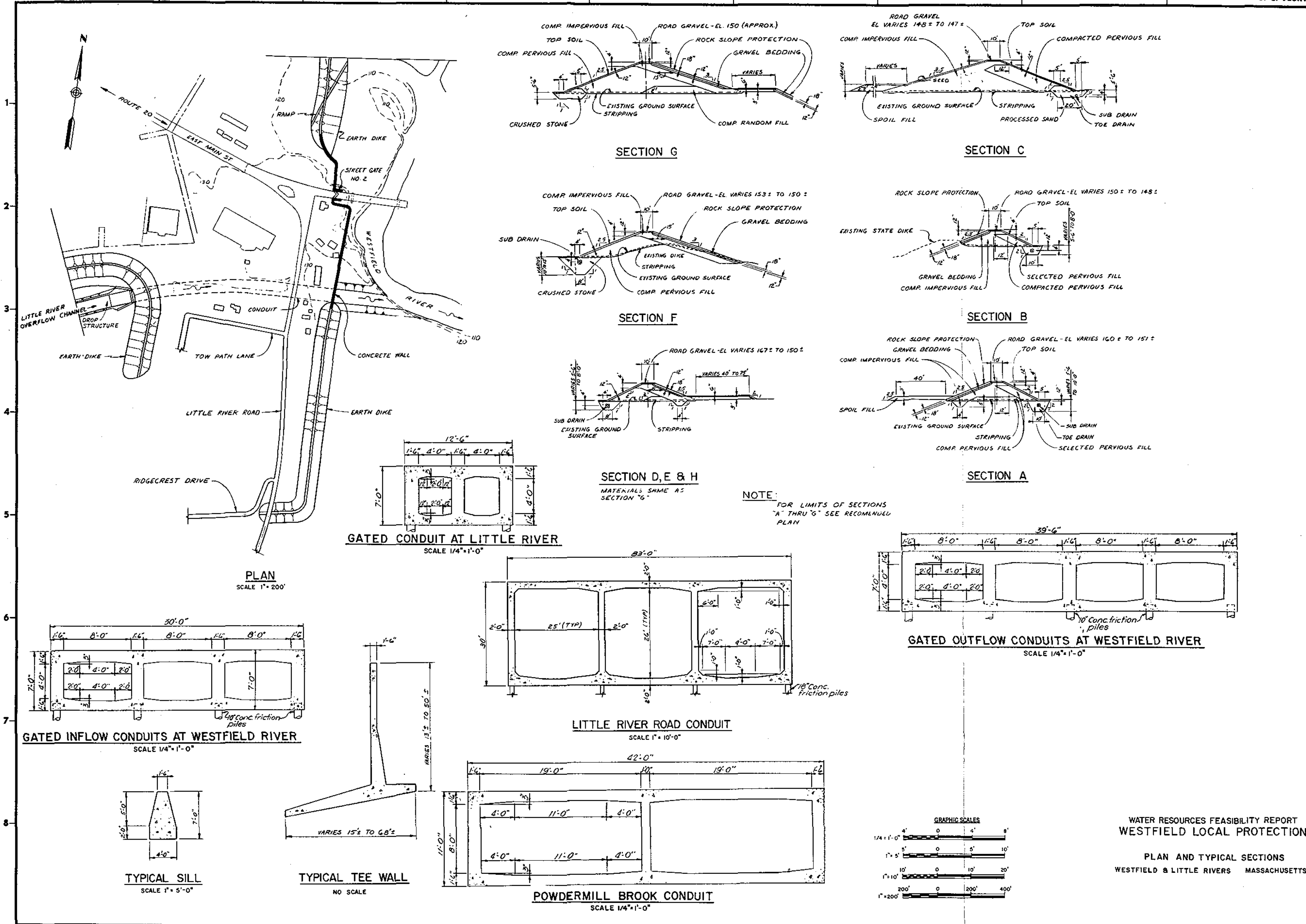
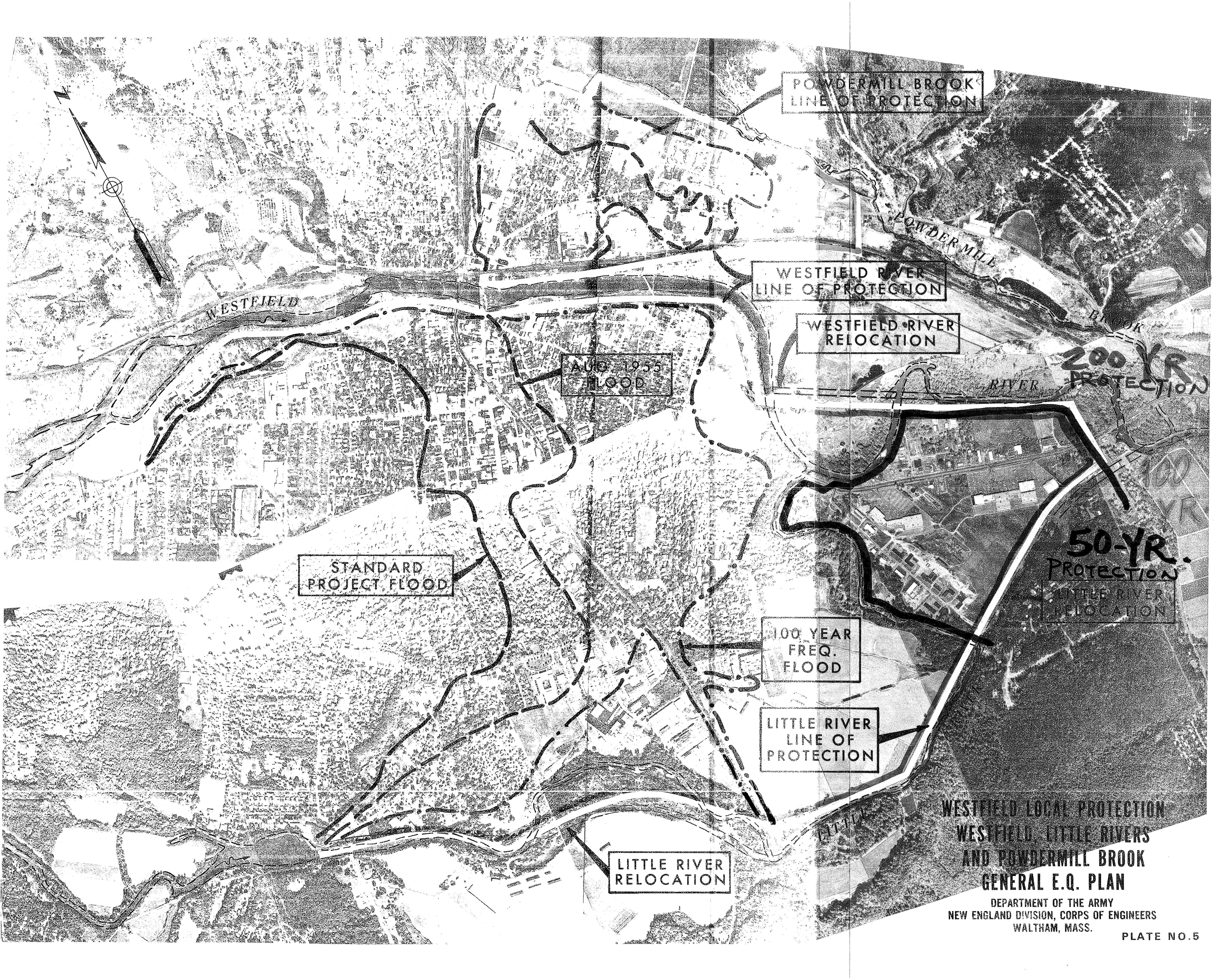


PLATE NO. 4



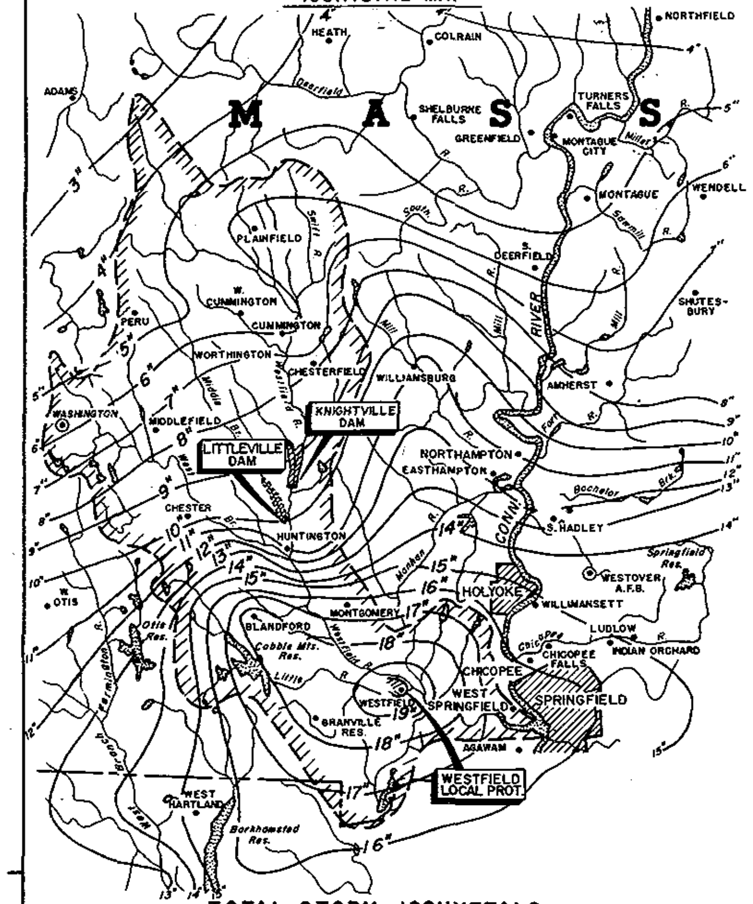
WESTFIELD LOCAL PROTECTION
WESTFIELD, LITTLE RIVERS
AND POWDERMILL BROOK
GENERAL E.Q. PLAN

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE NO.5

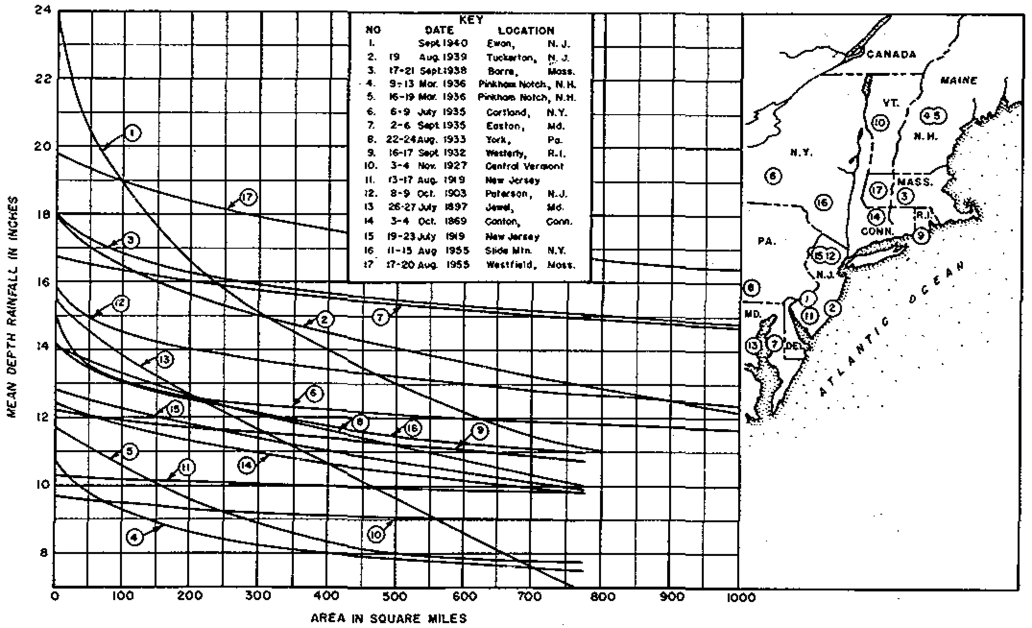
CORPS OF ENGINEERS U.S. ARMY

ISOHYETAL MAP



TOTAL STORM ISOHYETALS
AUGUST 17-20 1955
(HURRICANE "DIANE")

AREA-DEPTH CURVES
AND LOCATION OF STORM CENTERS

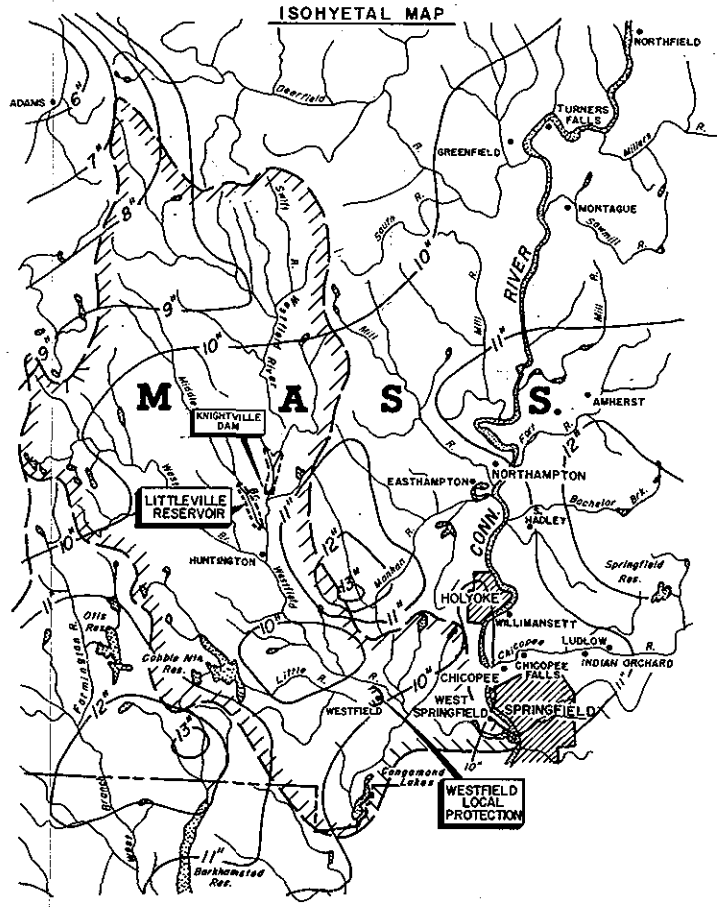


KEY

NO	DATE	LOCATION
1.	Sept. 1940	Ewan, N. J.
2.	19 Aug. 1939	Tuckerton, N. J.
3.	17-21 Sept. 1938	Barre, Mass.
4.	9-13 Mar. 1936	Pinkham Notch, N.H.
5.	16-19 Mar. 1936	Pinkham Notch, N.H.
6.	6-9 July 1935	Cortland, N.Y.
7.	2-6 Sept. 1935	Easton, Md.
8.	22-24 Aug. 1933	York, Pa.
9.	16-17 Sept. 1932	Westerly, R.I.
10.	3-4 Nov. 1927	Central Vermont
11.	13-17 Aug. 1919	New Jersey
12.	8-9 Oct. 1903	Paterson, N.J.
13	26-27 July 1897	Jewel, Md.
14	3-4 Oct. 1869	Canton, Conn.
15	19-23 July 1919	New Jersey
16	11-15 Aug 1955	Slide Mtn. N.Y.
17	17-20 Aug. 1955	Westfield, Mass.

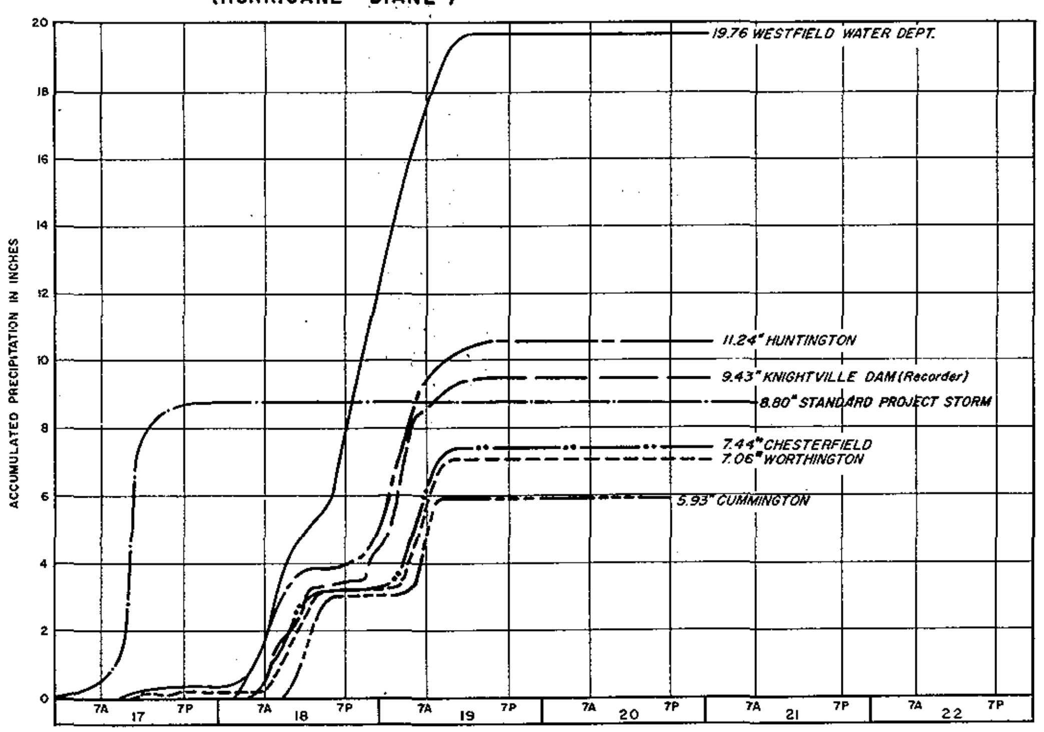
STORMS OF RECORD
NORTHEASTERN UNITED STATES

ISOHYETAL MAP

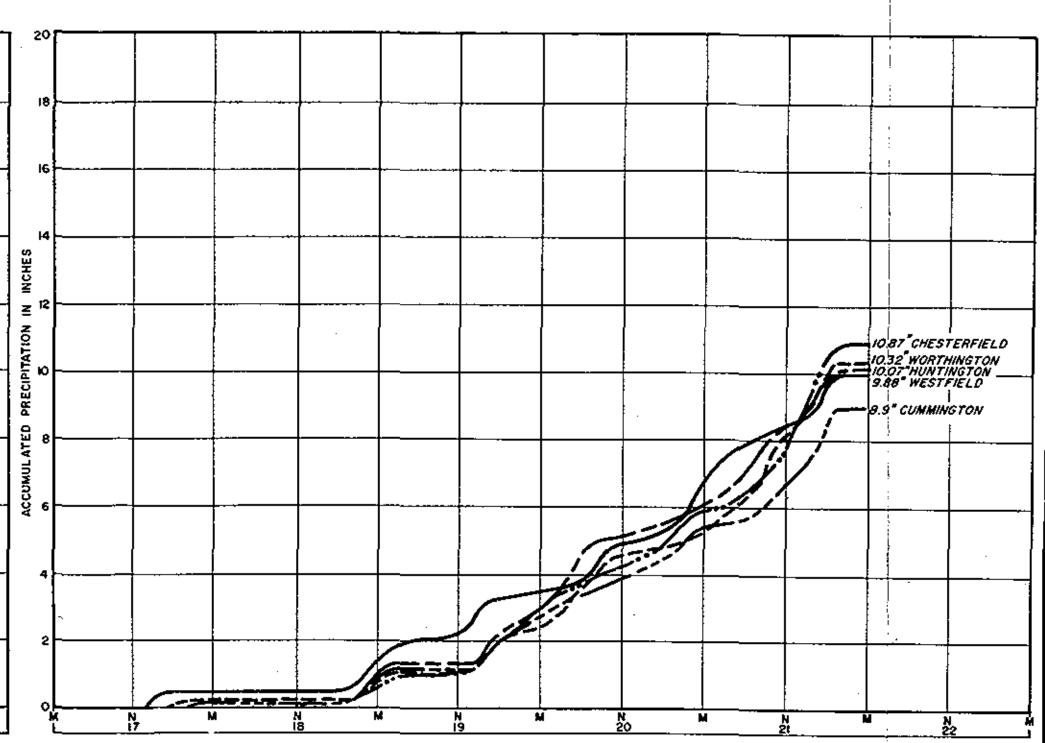


TOTAL STORM ISOHYETALS
SEPTEMBER 17-22, 1938

MASS CURVES



AUGUST 1955



SEPTEMBER 1938

REVISION	DATE	DESCRIPTION	BY

CORPS OF ENGINEERS. U. S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION
WALTHAM, MASS.

DR. BY | TR. BY S.J.C. | CK. BY E.P.S.

SUBMITTED

PROJECT ENGINEER

APPROVAL RECOMMENDED

CHIEF, HYD. & HYD. SECTION

APPROVAL RECOMMENDED

CHIEF P. & R. BRANCH

CONNECTICUT RIVER FLOOD CONTROL

WESTFIELD LOCAL PROTECTION

HYDROLOGIC DATA FOR RECORD STORMS

WESTFIELD & LITTLE RIVERS MASS.

APPROVED

CHIEF ENGINEERING DIVISION

DATE OCTOBER 1963

SCALE AS NOTED.

DRAWING NUMBER CT-1-4571

SHEET 1 OF 1

PLATE NO. 6

CORPS OF ENGINEERS

U. S. ARMY

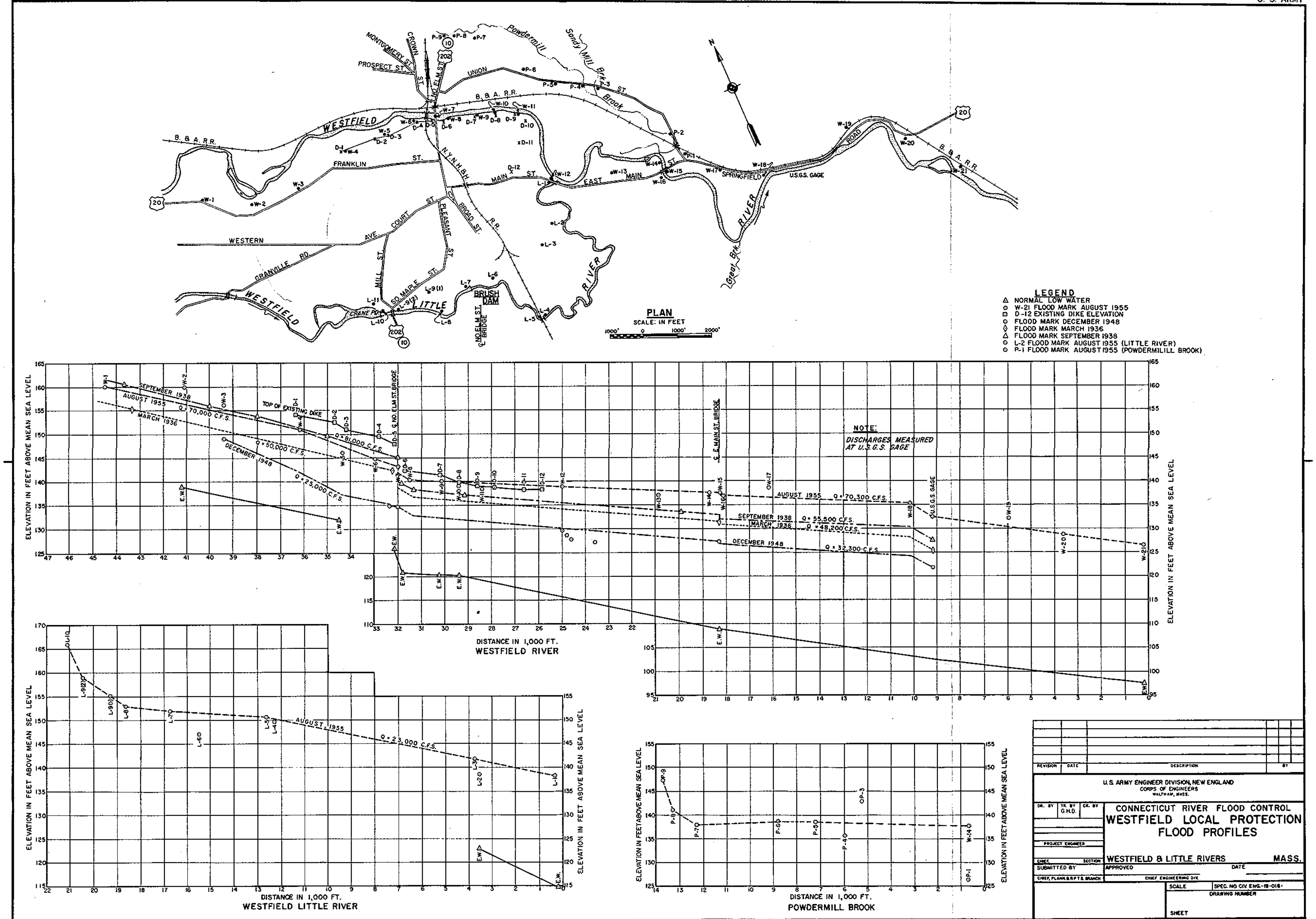
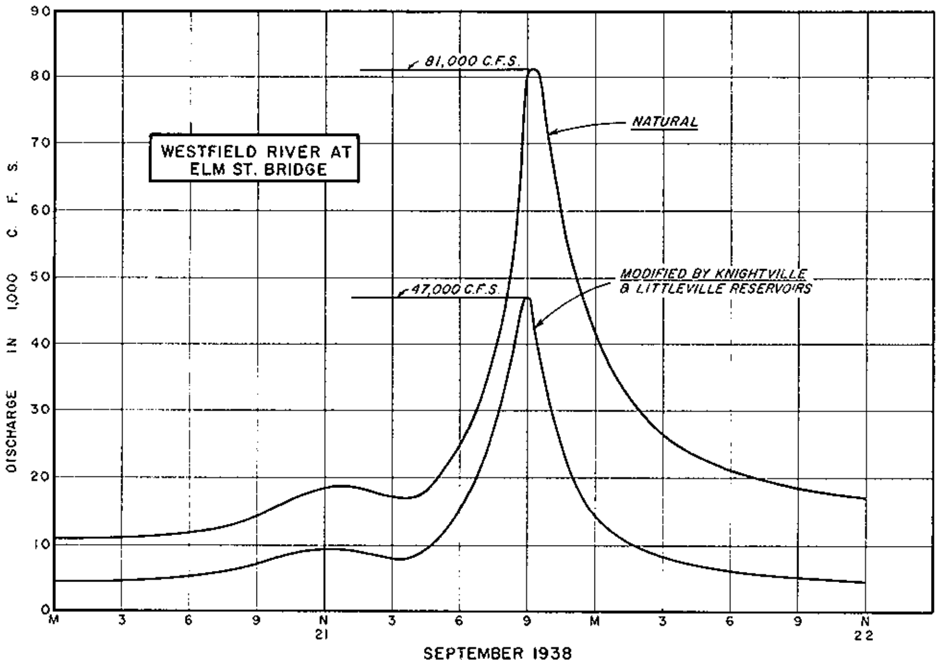
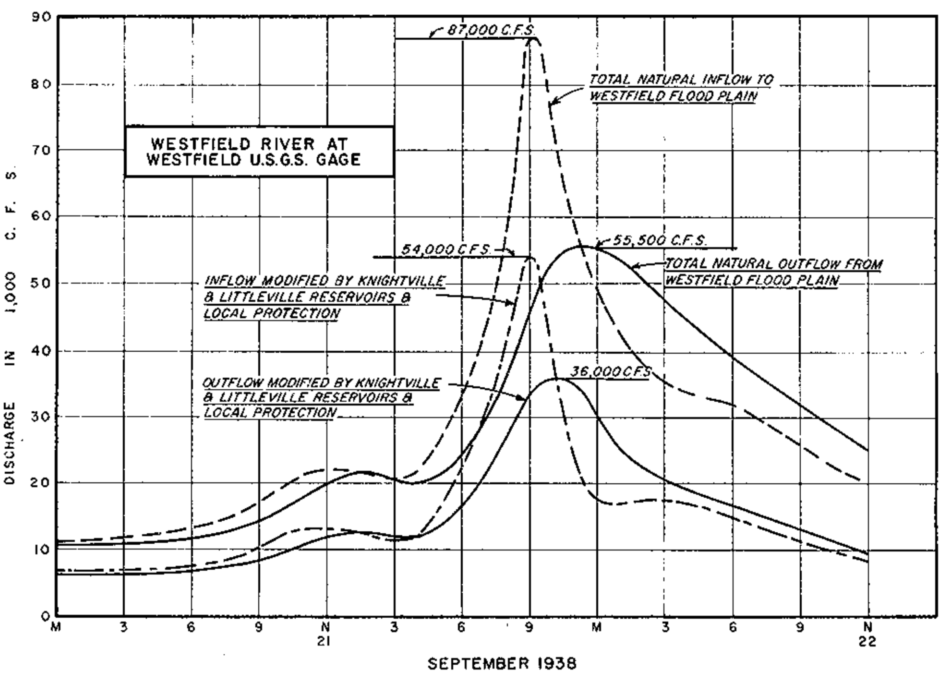


PLATE NO. 7





U.S. ARMY ENGINEER DIVISION, NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASS.	
DR. BY / TR. BY GHD. / CK. BY	CONNECTICUT RIVER FLOOD CONTROL WESTFIELD LOCAL PROTECTION SEPTEMBER 1938 FLOOD NATURAL & MODIFIED HYDROGRAPHS
PROJECT ENGINEER	
CHIEF SECTION	WESTFIELD & LITTLE RIVERS, MASS.
SUBMITTED BY	APPROVED DATE OCTOBER 1963
CHIEF, PLANN. & R.P.T.S. BRANCH	CHIEF ENGINEERING DIV.
SCALE	SPEC. NO. CIV. ENG.-19-016-
DRAWING NUMBER	
SHEET	

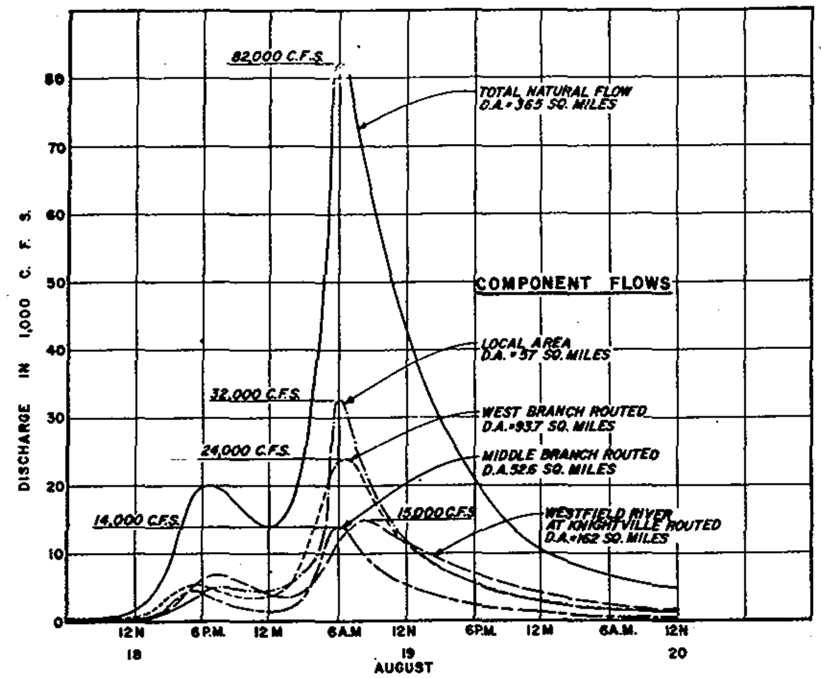
PLATE NO. 8

CORPS OF ENGINEERS

U. S. ARMY

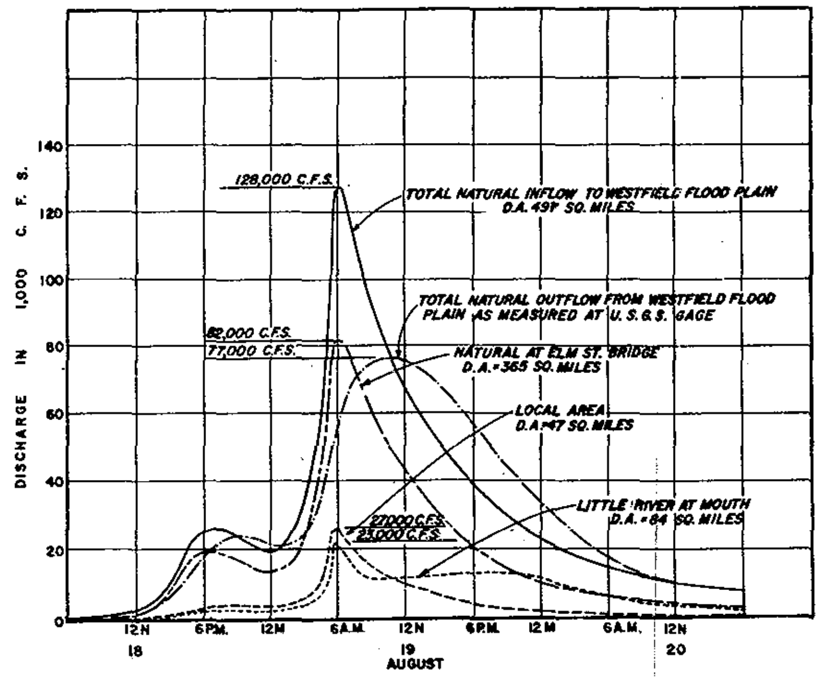
AUGUST 1955 FLOOD

ELM STREET BRIDGE

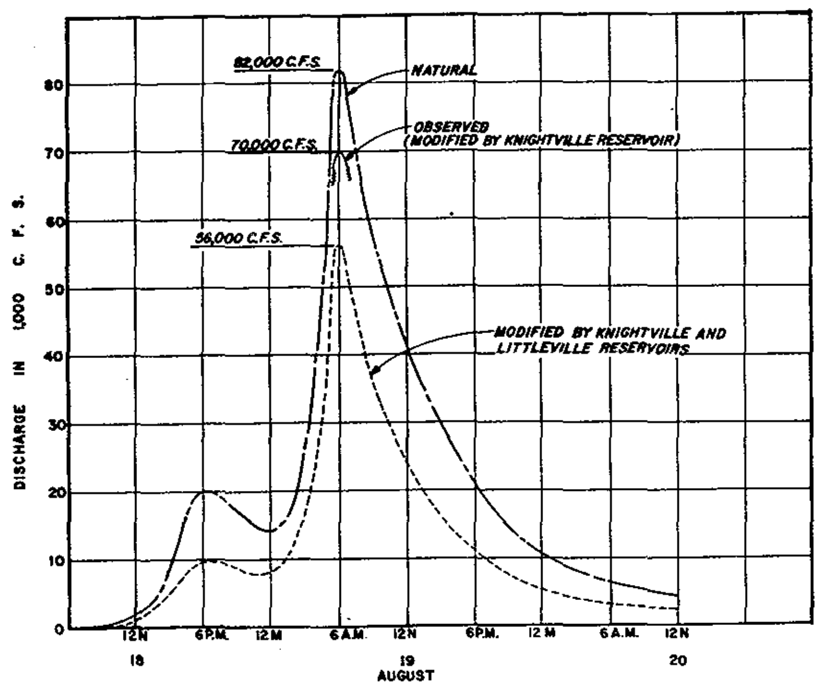


NATURAL

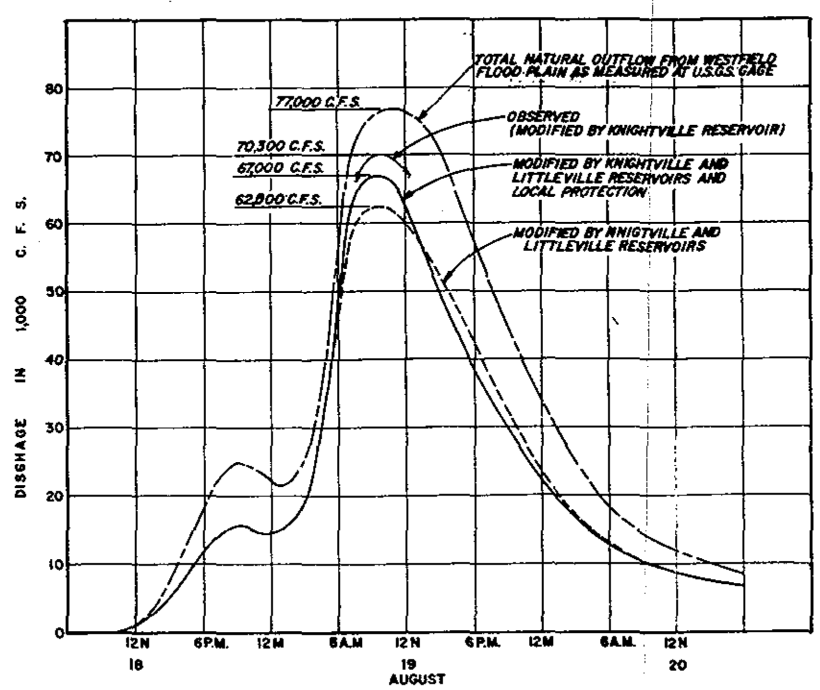
WESTFIELD U.S.G.S. GAGE



NATURAL



MODIFIED



MODIFIED

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

CONNECTICUT RIVER FLOOD CONTROL

WESTFIELD LOCAL PROTECTION

AUGUST 1955 FLOOD
NATURAL AND MODIFIED HYDROGRAPHS
WESTFIELD & LITTLE RIVERS MASS.

SUBMITTED BY

APPROVED

DATE OCTOBER 1963

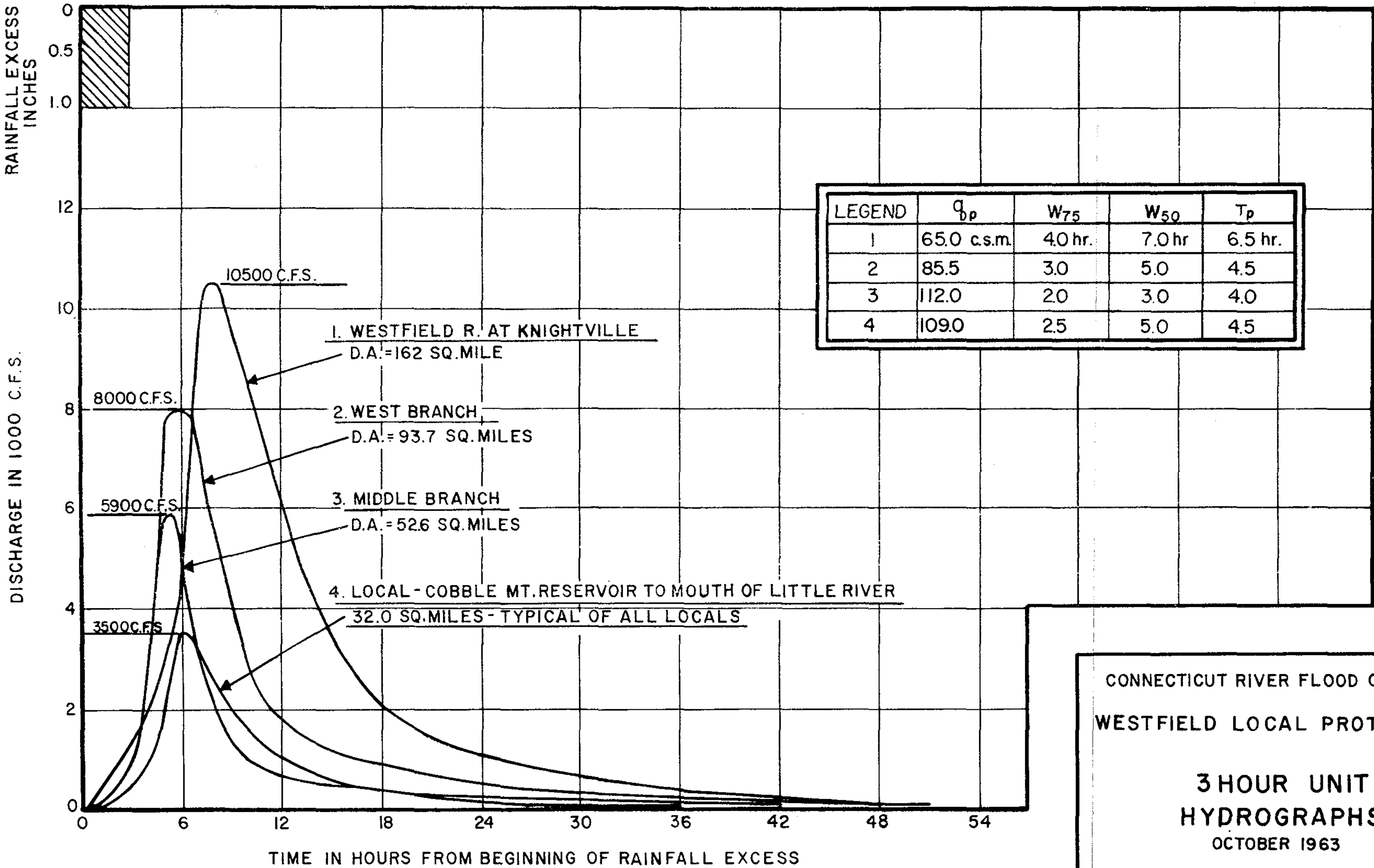
SCALE

SPEC. NO. CIV ENG-19-016-

DRAWING NUMBER

SHEET

PLATE NO. 9



LEGEND	q_p	W_{75}	W_{50}	T_p
1	65.0 c.s.m.	4.0 hr.	7.0 hr	6.5 hr.
2	85.5	3.0	5.0	4.5
3	112.0	2.0	3.0	4.0
4	109.0	2.5	5.0	4.5

CONNECTICUT RIVER FLOOD CONTROL

WESTFIELD LOCAL PROTECTION

3 HOUR UNIT HYDROGRAPHS

OCTOBER 1963

WESTFIELD & LITTLE RIVERS MASS

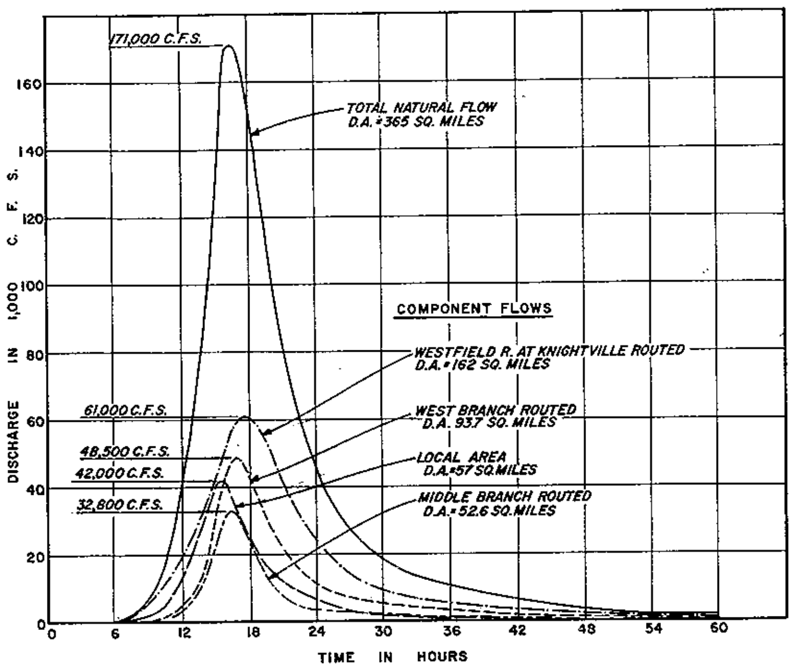
PLATE NO. 10

CORPS OF ENGINEERS

U. S. ARMY

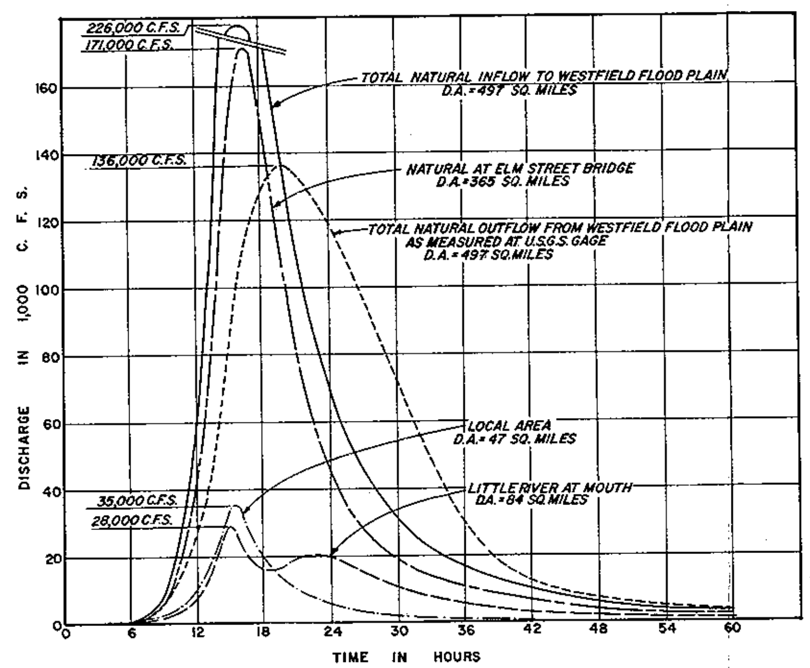
STANDARD PROJECT FLOOD

ELM STREET BRIDGE

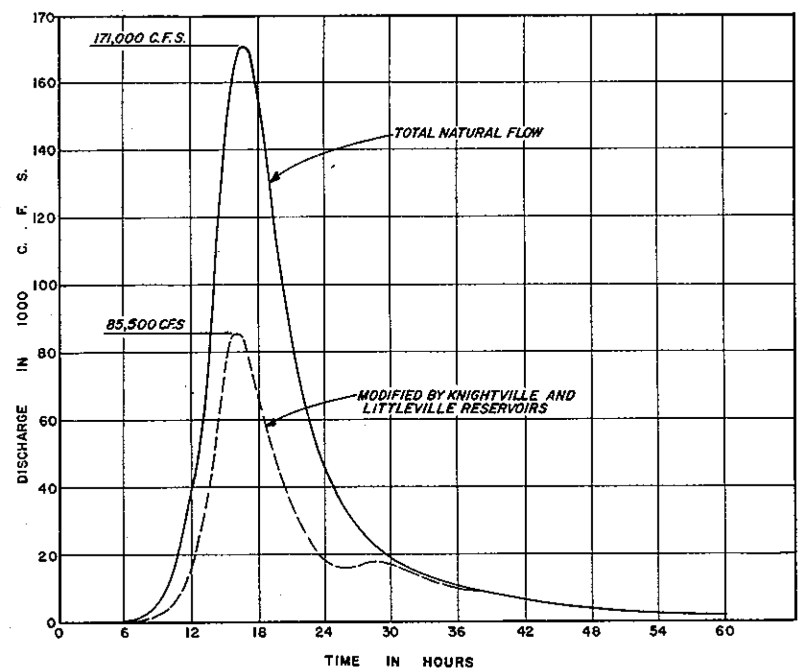


NATURAL

WESTFIELD U.S.G.S. GAGE



NATURAL



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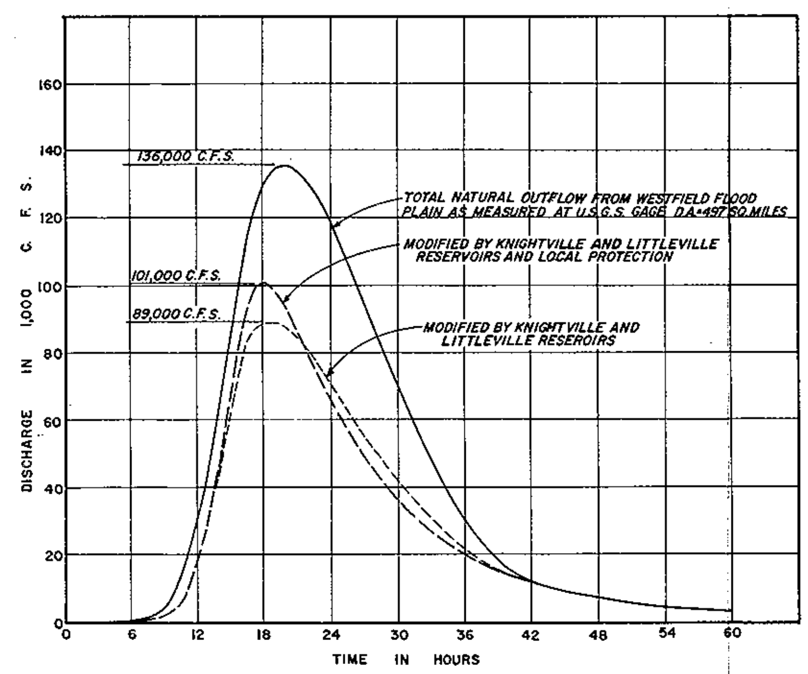


MODIFIED

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DR. BY | TR. BY | CK. BY

PROJECT ENGINEER

CHIEF, SECTION

SUBMITTED BY

CHIEF, PLANN. & RPTS. BRANCH

CONNECTICUT RIVER FLOOD CONTROL

WESTFIELD LOCAL PROTECTION

STANDARD PROJECT FLOOD
NATURAL AND MODIFIED HYDROGRAPHS

WESTFIELD & LITTLE RIVERS MASS.

APPROVED

CHIEF ENGINEERING DIV.

DATE OCTOBER 1963

SCALE

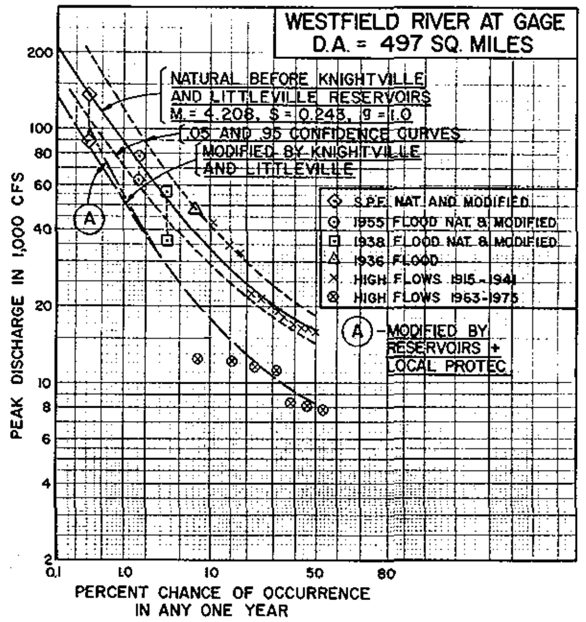
SPEC. NO. CIV. ENG.-19-016-

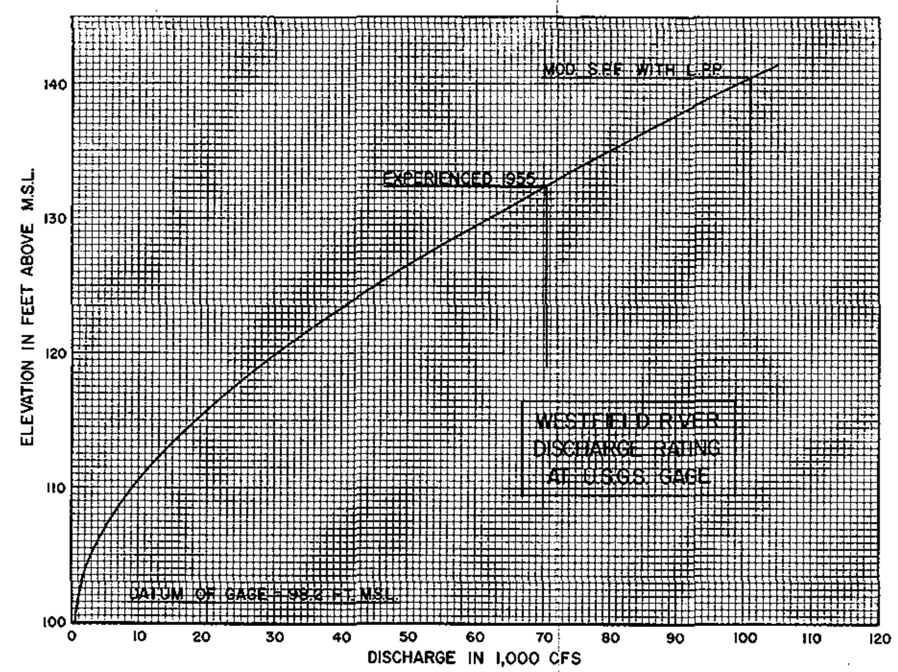
DRAWING NUMBER

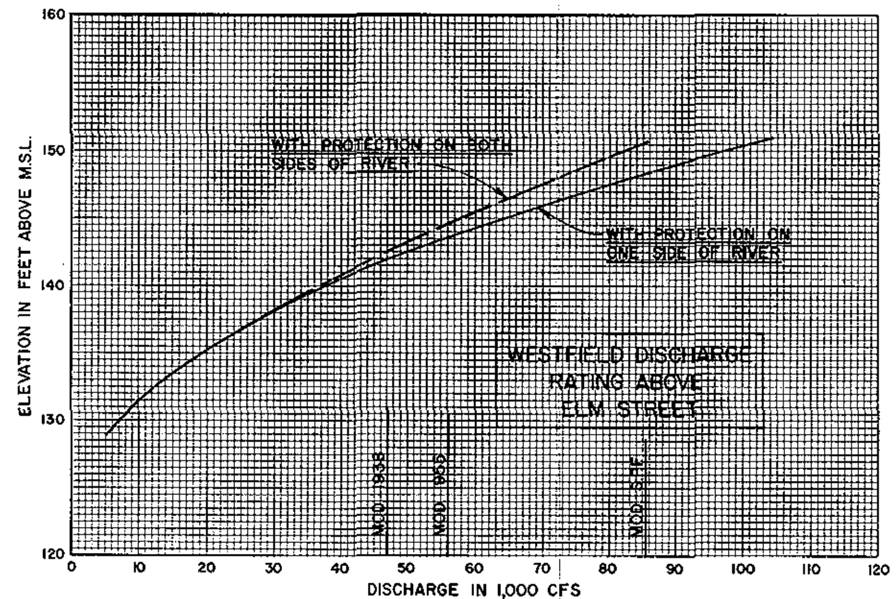
SHEET

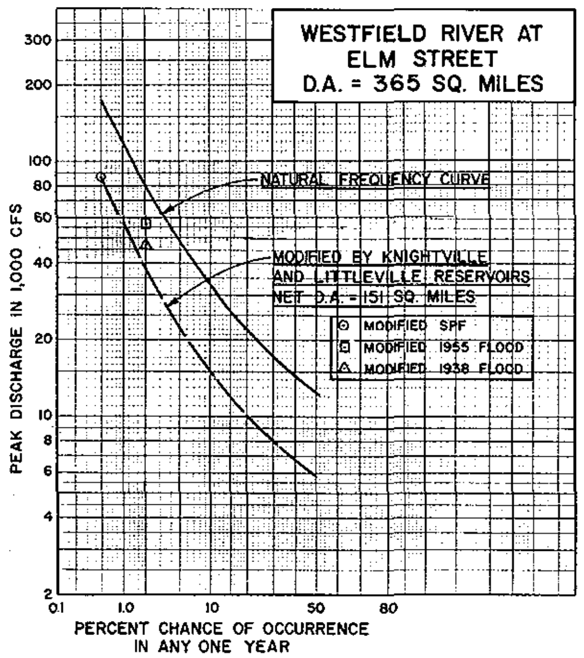
PLATE NO. 11

CORPS OF ENGINEERS | U. S. ARMY









GRAPHIC SCALES

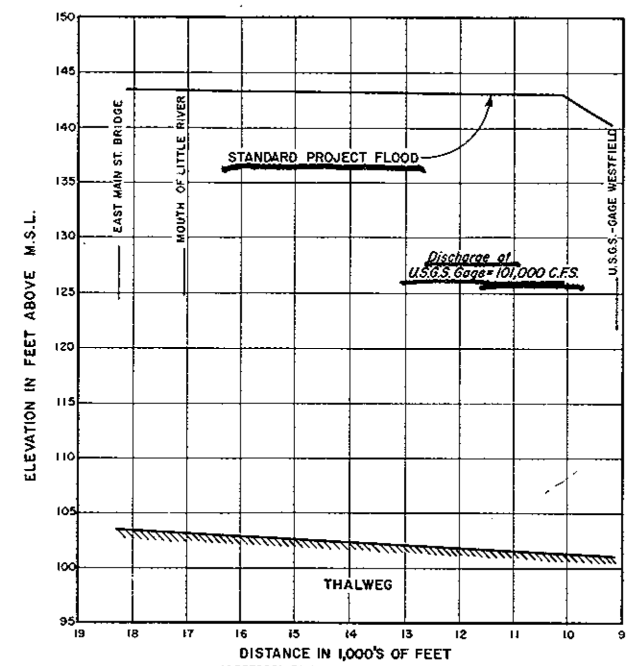
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

CONNECTICUT RIVER FLOOD CONTROL

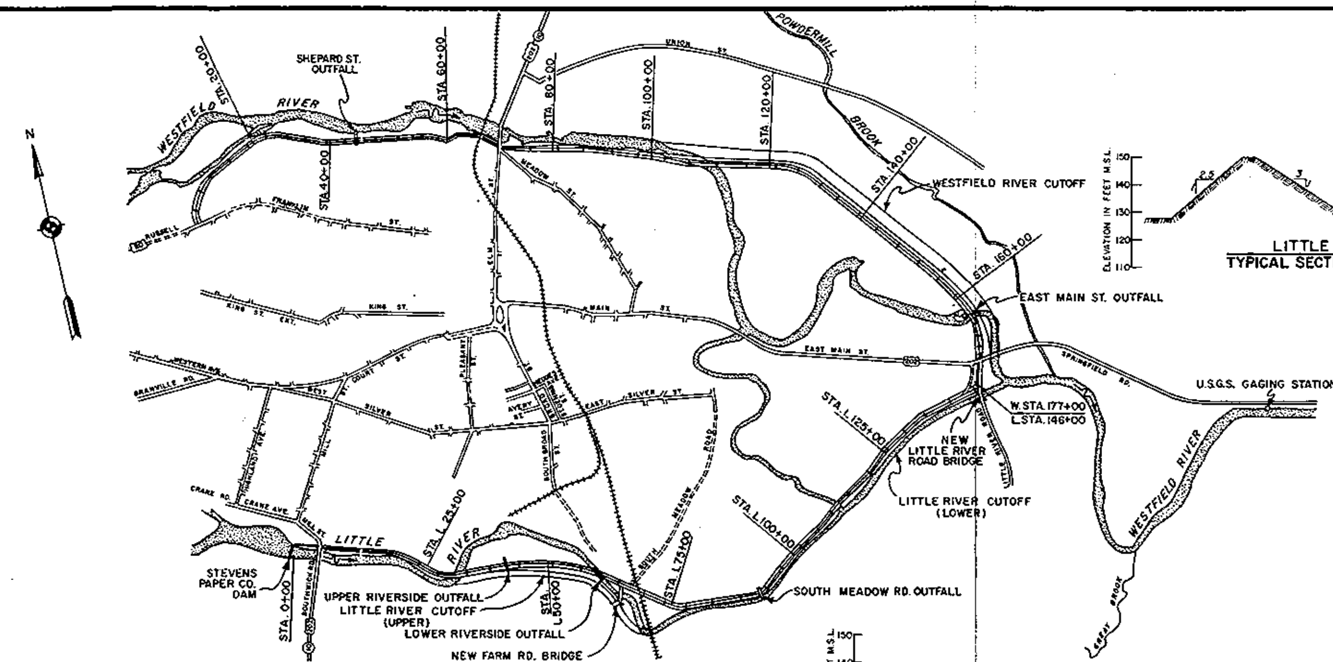
DISCHARGE FREQUENCIES & RATING CURVES
WESTFIELD RIVER AT WESTFIELD, MASS.

DATE MAY 1978

PLATE NO. 12

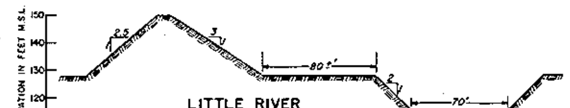


WESTFIELD RIVER
U.S.G.S. GAGE TO EAST MAIN ST. BRIDGE



WESTFIELD MASS.
LOCAL PROTECTION PROJECT

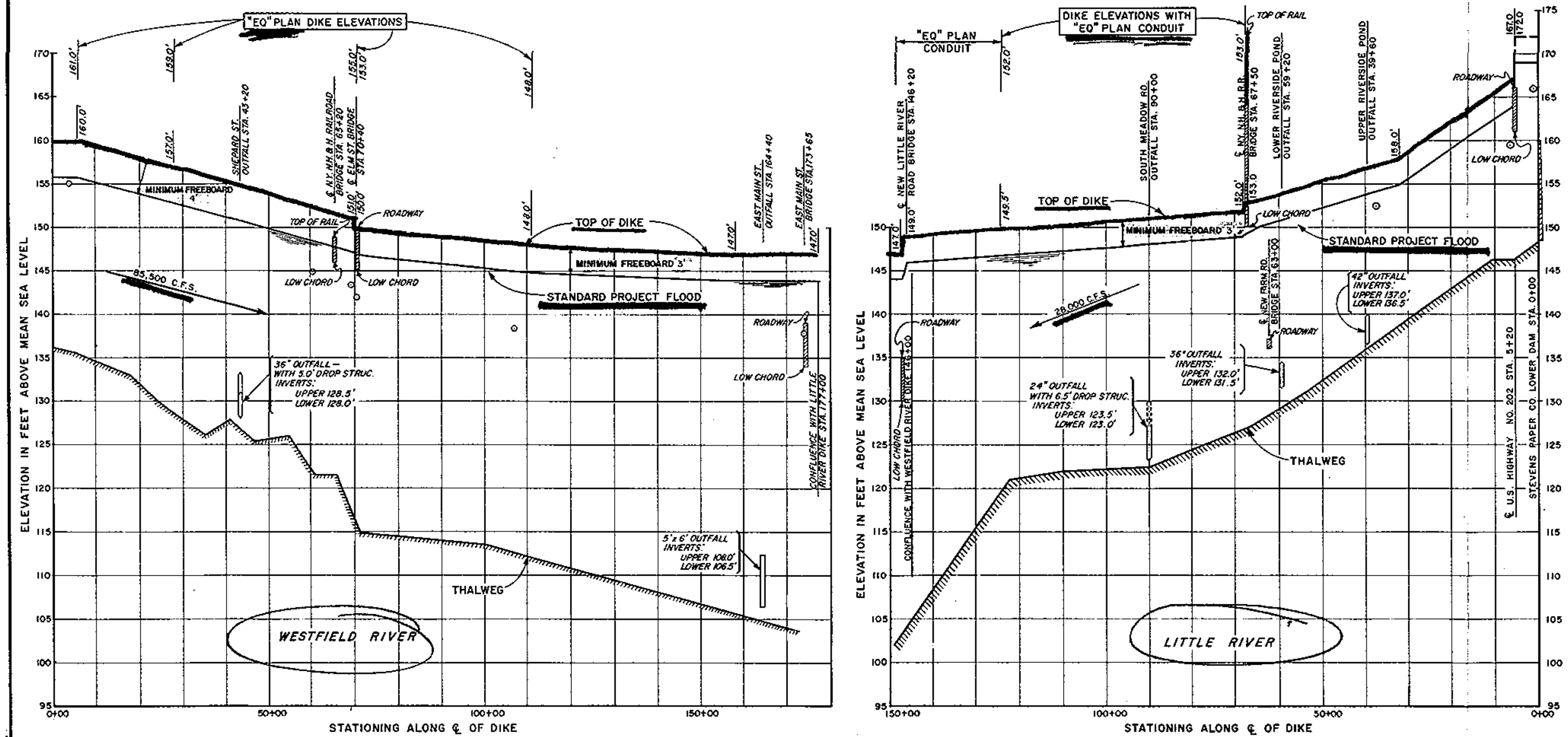
SCALE IN FEET



LITTLE RIVER
TYPICAL SECTION STA. 130+00

LITTLE RIVER
TYPICAL SECTION STA. 45+00

WESTFIELD RIVER
TYPICAL SECTION STA. 120+00



WESTFIELD AND LITTLE RIVER PROFILES

LEGEND

- THALWEG
- STANDARD PROJECT FLOOD PROFILE
- TOP OF DIKE AND/OR FLOOD WALLS
- FLOOD OF AUGUST 1955

NOTE: FOR "EQ" LEVEL OF PROTECTION ALONG POWDERMILL BROOK SEE PLATE NO. 3

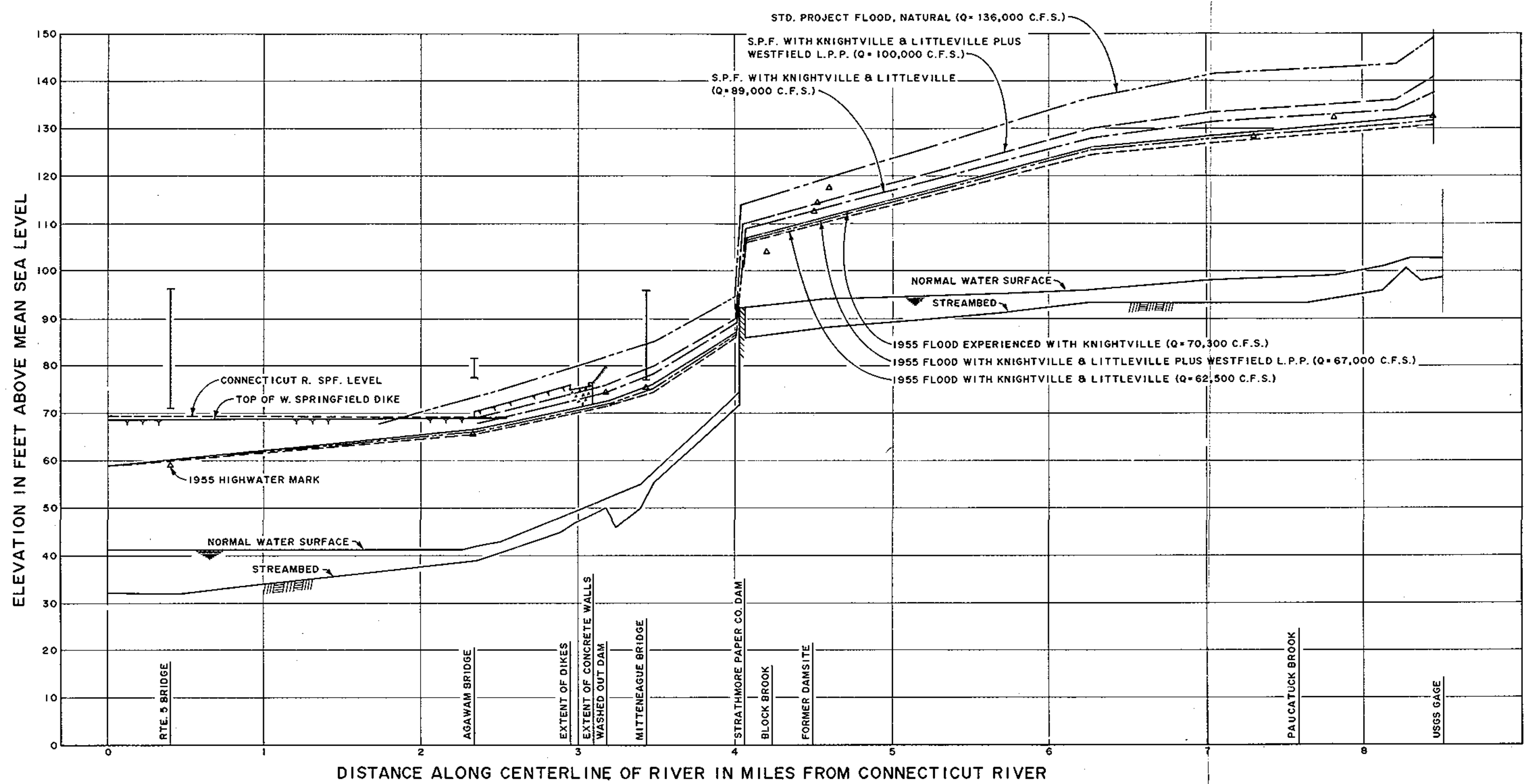
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DR. BY	TR. BY G.H.D.	CK. BY	CONNECTICUT RIVER FLOOD CONTROL WESTFIELD LOCAL PROTECTION "NED" PLAN AND PROFILES
PROJECT ENGINEER			
CHIEF, BRANCH			WESTFIELD & LITTLE RIVERS MASS.
SUBMITTED BY:			APPROVED: DATE OCTOBER 1963
CHIEF, PLANN. & RPTS BRANCH			CHIEF, ENGINEERING DIVISION
			SCALE: AS SHOWN
			DRAWING NUMBER
			SHEET 1 OF 1

PLATE NO. 13

CORPS OF ENGINEERS

U. S. ARMY



GRAPHIC SCALES

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED: CHIEF, SECTION

APPROVAL RECOMMENDED: CHIEF, TECH. ENG. BRANCH

REVIEWED: PROJECT ENGINEER

APPROVAL RECOMMENDED: CHIEF BRANCH

CONNECTICUT RIVER FLOOD CONTROL

COMPUTED WESTFIELD RIVER PROFILES

DOWNSTREAM OF GAGE AT WESTFIELD, MASS.

APPROVED CHIEF, ENGINEERING DIVISION DATE MAY 1978

SCALE | SPEC. NO. | DRAWING NUMBER | SHEET

PLATE NO. 14